THE UNIVERSITY OF ALBERTA

A MICROFAUNAL STUDY OF THE BEARPAW FORMATION, LETHBRIDGE AREA, ALBERTA

by

© ROWLAND ANAN-YORKE, B. Sc.

A THESIS

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Microfaunal Study of the Bearpaw Formation, Lethbridge Area, Alberta, submitted by Rowland Anan-Yorke, B. Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Forty-one species of Foraminifera from the Upper Cretaceous Bearpaw Formation in the Lethbridge area, Alberta, are figured and described. Seven families of arenaceous foraminifera are represented by eighteen species; thirteen families of calcareous perforate foraminifera aggregate twenty-two species and there is one species of calcareous imperforate foraminifera.

The foraminiferid genera (with the number of species described) occurring in the formation are: Hippocrepina, 1; Saccammina, 1; Ammodiscus, 2; Reophax, 1; Haplophragmoides, 6; Ammobaculites, 1; Trochammina, 1; Verneuilina, 1; Verneuilinoides, 1; Gaudryina, 1; Dorothia, 1; Tritaxia, 1; Quinqueloculina, 1; Lenticulina, 1; Nodosaria, 1; Dentalina, 3; Pyrulina? 1; Glandulina, 1; Neobulimina, 1; Praebulimina, 2; Eoeponidella, 1; Valvulineria, 1; Spirillina? 1; Heterohelix, 1; Globigerina, 1; Hedbergella, 1; Nonionella, 1; Gyroidina, 1; Anomalinoides, 1; Gavelinella, 1; and Gavelinella? 1.

Many species of the arenaceous foraminifera which form the dominant component of the Bearpaw microfauna are long-ranging and a zonation is not readily apparent. For correlation purposes the following "zones" have been tentatively designated above the base of the Bearpaw:

i. Dorothia sp. "Zone", 12-35 feet above.

ii. Gavelinella? sp. "Zone", 56-115 feet above.

iii. Anomalinoides sp. "Zone", 200-450 feet above.

These "zones" have been correlated with Given's (1969) zones of the Bearpaw in Castor area, Alberta; Caldwell and North's (1964) zones in the Saskatchewan River valley; and Loranger and Gleddie's (1953) zones in the southwestern Saskatchewan and southeastern Alberta.

On the basis of foraminiferal associations in the Bearpaw Formation of the thesis area, six cycles of fluctuation of water depth have been recorded, mainly indicative of brackish conditions.

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CHAPTER ONE - INTRODUCTION

The Bearpaw Formation represents the deposits of the last advance of the Late Cretaceous sea within the western Canadian interior. This sea extended westerly at least as far as the Alberta Foothills, south of the Bow River, and northerly in the plains region to the Edmonton area of central Alberta. Lethbridge is situated at least 60 miles east of the presently known western margin of this sea as indicated by the Bearpaw exposures at Lundbreck, Alberta.

Many of the faunal taxa, ammonites, such as Baculites and Placenticeras; pelecypods such as Arctica, Ostrea, Gervillia and some of the species of foraminifera which flourished in previous seas of the western Canadian interior, became important components of the Bearpaw Sea. The record of these organisms in this final marine invasion has been used by various workers in interpreting the paleoecology of the Bearpaw Formation and in distinguishing the "zones" reflecting these changes.

The Upper Cretaceous (Campanian) Bearpaw Formation of southeastern Alberta and southwestern Saskatchewan was divided by Loranger and Gleddie in 1953 into six "zones" on the basis of core holes drilled in southwestern Saskatchewan and in the Dunmore area, near Medicine Hat, Alberta. In descending order, the zones are as follows; Gyroidina sp. and Ostracoda Zone; glauconite Zone; Ammodiscus sp. Zone; Anomalina sp. Zone, Plectina smithia Zone; Tritaxia cryder-

manensa Zone. In their conclusions, these authors said: "in the western plains area in the vicinity of Lethbridge, three of these zones (Tritaxia crydermanensa, Plectina smithia, Anomalina sp.) are present, but evidence adduced to date indicates that the forms are more brackish in habitat and that facies variations exist between the western and the eastern plains area."

To test the validity of the conclusions of Loranger and Gleddie, a number of outcrop samples were collected from the Bearpaw Formation along the Oldman River and St. Mary River valleys in the Lethbridge area, Alberta in July, 1966 by Dr. John H. Wall of the Research Council of Alberta and by the writer and Dr. Wall in October, 1968. These samples form the basis for the microfaunal studies of this thesis dissertation.

The thesis is concerned with the analysis of the microfaunal assemblage of the Bearpaw Formation in the Lethbridge area, Alberta, and an interpretation of the paleoecologic significance of the microfaunal association of the formation. Correlations are made with those of southeastern Alberta and southwestern Saskatchewan as drawn up by Loranger and Gleddie (1953) and Caldwell and North (1964), and with those of the Castor area of central Alberta by Given (1969).

Previous Microfaunal Work

Microfaunal studies on the Bearpaw Formation are

limited. Wickenden (1932), in studies of Upper Cretaceous samples from various localities of the Prairie Provinces of Canada, recognized twelve new species of foraminifera, five of which were characteristic of the Bearpaw Formation. Loranger and Gleddie's (1953) zonation of the Bearpaw was based on recognition of 115 species of microfauna comprising 52 genera. They recognized many new species of foraminifera, but the formal descriptions of the new species were not published.

Caldwell and North (1964), from their studies of foraminifera from core hole samples in the South Saskatchewan River valley, between the towns of of Outlook and Pennant in southwestern Saskatchewan, recognized three foraminiferal zones: a lower Gaudryina sp. Zone; a middle Anomalinoides henbesti Zone; an upper Haplophragmoides excavata Zone. These zones correspond with Loranger and Gleddie's (1953) zonation of Tritaxia crydermanensa and Plectina smithia Zones; Anomalina sp. Zone; Ammodiscus sp. and Gyroidina sp. Zones, respectively.

Given (1969) recognizes the following zones from the Bearpaw in the Castor area: a lower Eoeponidella strombodes Zone and an upper ? Cassidella sp. A. "Zone". Given's E. strombodes Zone correlates with the Anomalina sp. Zone of Loranger and Gleddie and the Anomalinoides henbesti Zone of Caldwell and North.

CHAPTER TWO - STRATIGRAPHY

Regional Setting

The Bearpaw Formation is a marine shale lying between the non-marine Belly River and Edmonton (St. Mary) Formations in the south half of Alberta. The stratigraphy of the formation indicates that ".. the sea came from the southeast during Upper Campanian time and slowly advanced over the previously deposited fresh-water sediments of the Pale beds" (Link and Childerhose, 1931). Williams and Burk (1964) said that the clastic materials making up the Bearpaw sediments were probably discharged from the tectonically active belt of the northwest. They estimated the total thickness of the formation to be 1200 feet and indicated that the formation thins in the westerly and northwesterly directions.

The formation consists generally of dark grey shales, silty shales, ferruginous concretions and numerous thin ash beds - which indicate a slow deposition of the clastic sediments (Link & Childerhose, 1931). Folinsbee et al. (1960, 1961, 1965) estimated the age of a thin ash bed, 65 feet above the base of the Bearpaw on the west, north and east sides of the Cypress Hills by potassium-argon dating as 75 ± 4 million years. Ower (1960) indicated that the upper contact of the Bearpaw is transitional and passes vertically and laterally into the Edmonton Formation in central Alberta. The stratigraphic position of the Bearpaw Formation is shown

in Figure 1.

Detailed description of the stratigraphy and paleontology of the formation can be found in the works by various authors, among whom are Stanton and Hatcher (1903, 1905), Dowling (1917), Williams and Dyer (1930), Wickenden (1932), Russell and Landes (1940), Furnival (1946), and Lines (1947).

Bearpaw Stratigraphy of the Lethbridge Area

A detailed description of the lithology, index fossil zones and distribution of the Bearpaw Formation in the Lethbridge area is given by Link and Childerhose (1931). The formation occurs beneath thick glacial drift, but outcrops along the Oldman River and St. Mary River valleys and in coulees. Descriptions of excellent exposures of the Bearpaw strata in the Lethbridge area are located by Irish (1967) in the Geological Survey of Canada Map 20 - 1967.

The contact between the Bearpaw and the underlying Oldman Formation is formed by a thin brown ferruginous sandstone ranging from eight inches to two feet thick. Link and Childerhose (1931) estimated the thickness of the formation as 726 feet. Irish (1967) estimated it to be 720 feet. The lower one-third of the formation consists of well bedded, dark shales and the upper two-thirds contains three distinct sandstone members which, in ascending order are: Magrath Sandstone, Kipp Sandstone and Ryegrass Sandstone.

The Magrath Sandstone consists of medium grained, light

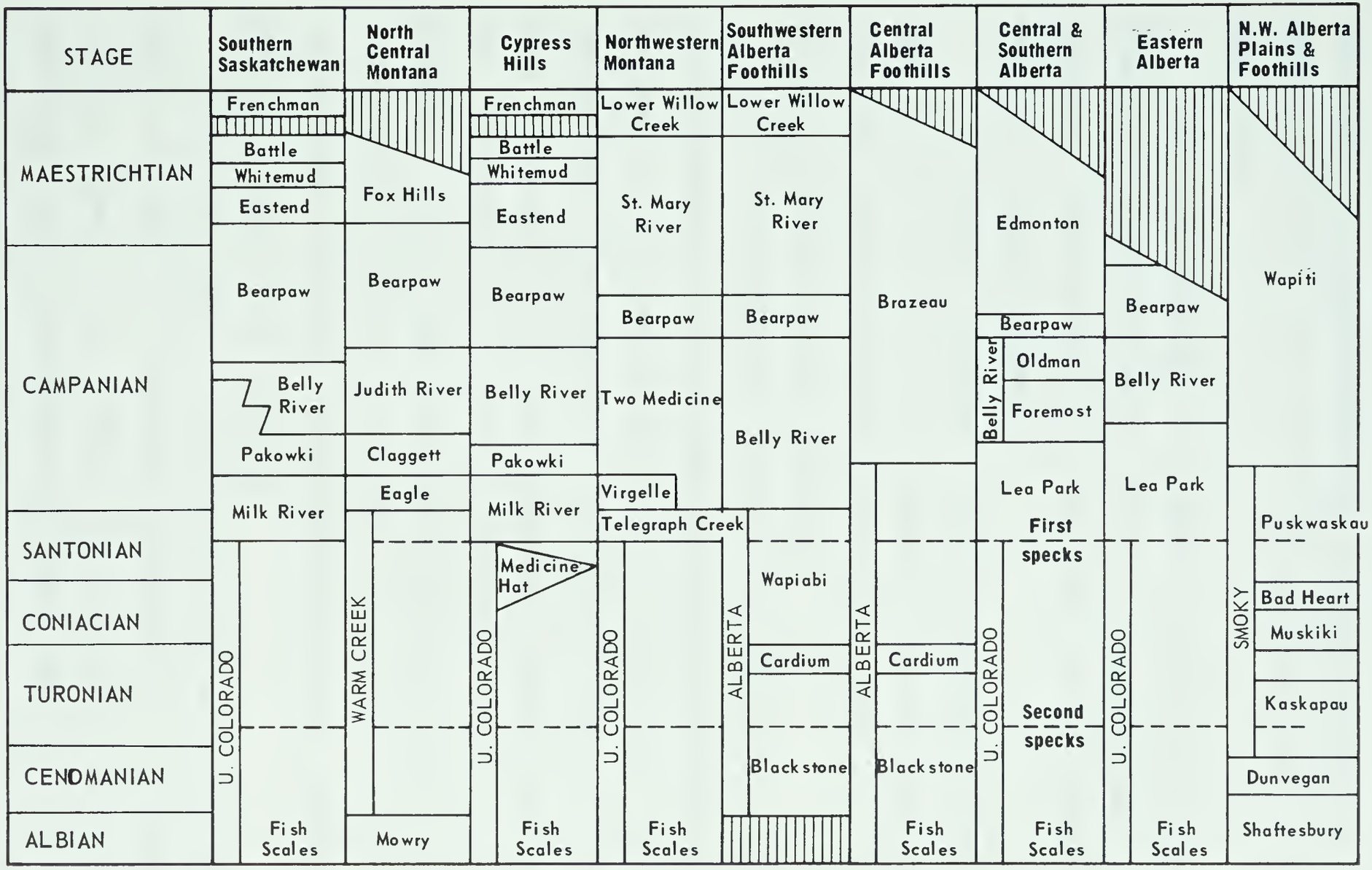


FIGURE 1: UPPER CRETACEOUS CORRELATION CHART, WESTERN CANADIAN PLAINS AND FOOTHILLS (after Williams and Burk, 1964)

grey to bluish sands, shaley sands and some pure shale breaks. The Magrath is characterized by a great profusion of Arctica which also occurs less abundantly in other parts of the Bearpaw shales.

The Kipp Sandstone is a dense, coherent and fine grained greenish blue shaley sand. Abundant Placenticeras and Baculites are found primarily in the shales lying between and above this sandstone member.

The Ryegrass Sandstone consists of fine grained, bright blue sands, interbedded with shales. The shale unit overlying the Ryegrass becomes more sandy towards the overlying non-marine Blood Reserve Formation.

Link and Childerhose (1931) calculated the positions and thicknesses of the sandstone members as follows: Magrath Sandstone, thickness 62 feet, top 272 feet above the base of the Bearpaw; Kipp Sandstone, thickness 40 feet, top at 410 feet above the base of the formation; Ryegrass Sandstone, 90 feet thick with its top at 642 feet above the base of the Bearpaw. Irish (1967) gave the thicknesses and positions of the sandstone members as 62 feet, 28 feet and 27 feet, occurring at about 246 feet, 385 feet and 640 feet, respectively, above the base of the Bearpaw.

There are twenty-two ash beds (Link and Childerhose, 1931) and bands of elliptical ferruginous or calcareous concretions some of which contain well preserved fossils. A three foot thick glauconite bed occurs about 30 feet above the top of the Ryegrass Sandstone (Link and Childerhose,

1931). Gypsum is also abundant and occurs in the form of selenite occupying the partings of the shales.

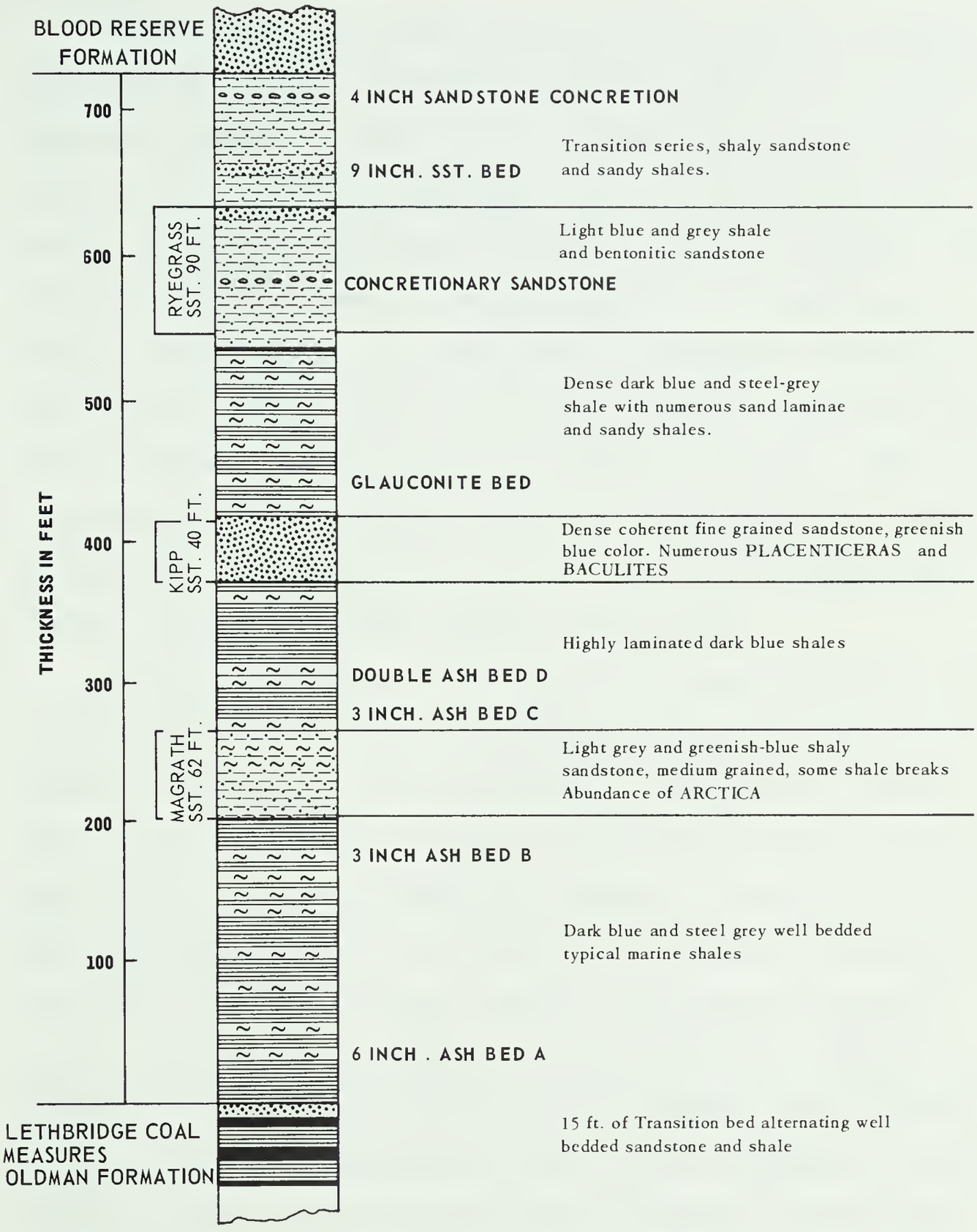


FIGURE 2: COLUMNAR SECTION OF BEARPAW SHALES NEAR LETHBRIDGE, ALBERTA (after Link and Childerhose, 1931)

CHAPTER THREE - PALEOECOLOGY

Paleoecology has been defined as the study of the complex interrelationships between ancient organisms and their habitats (Laporte, 1968, p. 2). Paleoecology is related to ecology, the latter is concerned with explaining the interaction of living organisms with their physical, chemical and biological environment. The distribution of organisms, including foraminifera, is influenced by types of substrate, food supply, temperature, turbidity, organic competition and other chemical, mechanical and biological factors. Many of these environmental factors cannot be determined in a fossil assemblage. Therefore, the use of fossils in interpreting ancient environments has serious limitations.

Takayanagi (1960, p. 58) said that frequent changes occur in the formation of fossil assemblage from the living association. Before the living population (biocoenose) becomes part of the sediments, it may be transported from its original habitat to form a secondary grouping through sieving by the surrounding media or by mixing with another biocoenose. The mixed group would form a fossil assemblage following burial and diagenetic changes of the sediments. Phleger (1960, p. 2) believes that benthonic organisms are affected by the nature of the water and the type of sediments at the bottom on which they live, and that planktonic foraminifera are influenced by environmental changes at various depths.

Various workers have shown the distribution of recent or fossil foraminifera. Graham and Church (1963, p. 12)

indicated the distribution for the following groups of foraminifera:

i. The abundance of arenaceous (agglutinated) foraminifera tends to suggest a muddy bottom environment beneath a quiet water column in the Late Cretaceous at the San Mateo County locality, since the building of arenaceous shells is favoured by this kind of habitat.

ii. Recent nodosariids are both eurythermal and eurybathyal, with occurrences being common in temperate water of the outer neritic zone.

iii. The buliminids and discorbids have a wide bathymetric distribution in Recent seas, and may have had in the past.

iv. Planktonic organisms reveal proximity to the open sea or fairly strong ocean currents for a limited period.

The paleoecology of the Bearpaw Formation in the Lethbridge area, is based on the distribution pattern of foraminifera as outlined above.

Characteristics of the Bearpaw Microfauna in the Lethbridge Area.

The Bearpaw Formation in the Lethbridge area, Alberta, is characterized by an association of abundant foraminifera, a few poorly preserved ostracods, rare fish bones, partial

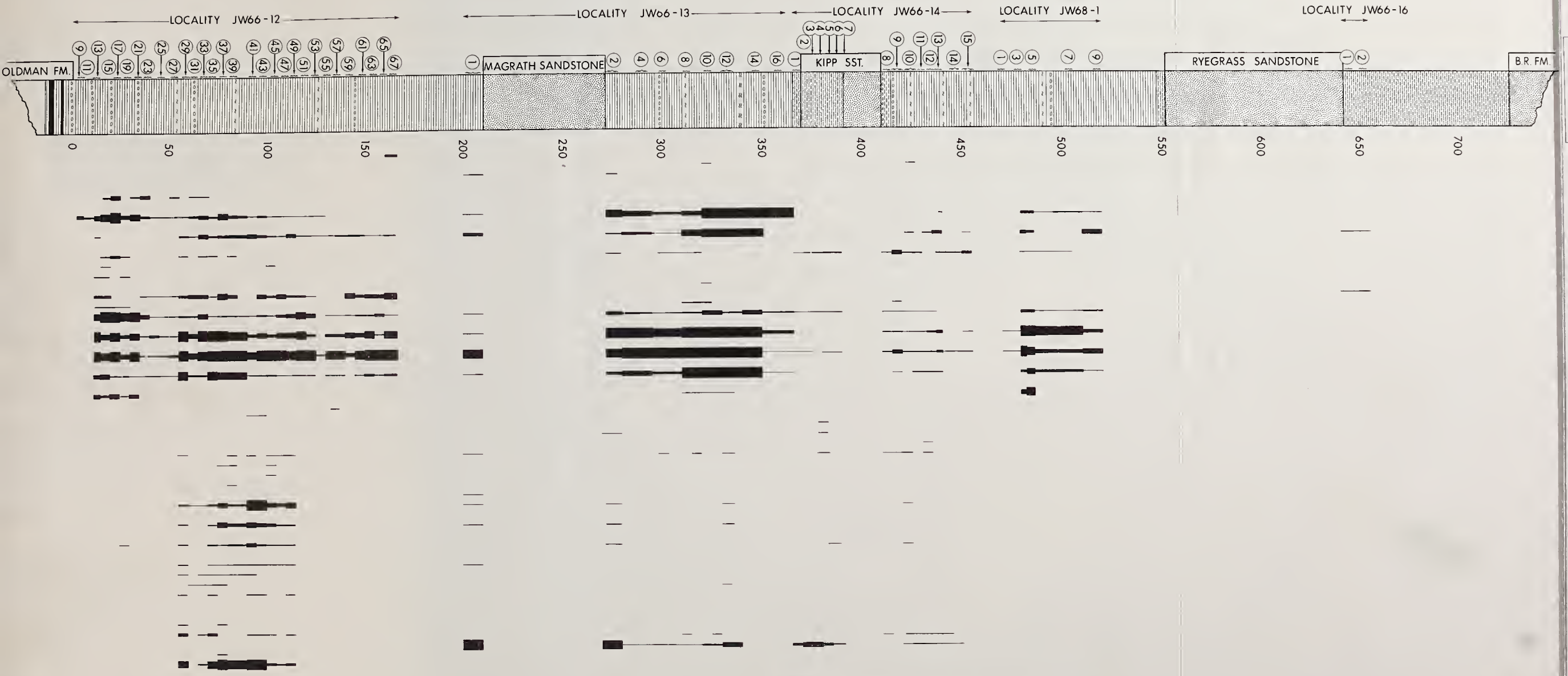
radiolarian? skeletons, spines of echinoderms? and scolecodonts?

The foraminiferal assemblage which is the dominant and the most important component of the Bearpaw microfauna comprises forty-one species representing thirty genera and twenty families. Of the forty-one species, eighteen have arenaceous (agglutinated) tests; nineteen have calcareous perforate tests and are benthonic varieties; three belong to the planktonic group and there is one calcareous imperforate form (miliolid).

The arenaceous foraminifera are usually highly pyritized and often have distorted or collapsed chambers, probably caused by compaction as the enclosing sediments were deposited. However, the assemblage as a whole is fairly well preserved. Most of the calcareous foraminifera, especially Neobulimina, Praebulimina, and Gavelinella?,occur in the 120 mesh screen (0.125mm.) or finer.

Microfaunal Assemblages

The Range Chart, Figure 3, shows the distribution of the foraminifera in the Bearpaw Formation in the Lethbridge area. Most of the samples at Localities JW66-12, JW66-13, JW68-1, yielded common to abundant foraminifera with arenaceous (agglutinated) foraminifera being the dominant component. There is no definite pattern of zonation, but the occurrences of calcareous foraminifera at the interval 56-115 feet above the base of the formation and in the 10 feet of shales just



Hippocrepina sp.
Saccammina sp. cf. S. alexanderi
Ammodiscus sp. cf. A. cretaceus
Ammodiscus sp.
Reophax sp. cf. R. troyeri

Haplophragmoides sp. cf. H. linki

Haplophragmoides kirki

Haplophragmoides sp. cf. H. rugosa
Haplophragmoides sp. 1
Haplophragmoides sp. 2
Haplophragmoides sp. 3
Haplophragmoides spp.
Ammobaculites sp.
Trochammina albertensis

Verneuilina canadensis

Verneuilinoides bearpawensis

Gaudryina bearpawensis

Dorothia sp.
Tritaxia sp.
Quinqueloculina sphaera
Lenticulina sp. cf. L. alexanderi
Lenticulina sp.
Nodosaria sp.
Dentalina sp. cf. D. basiplanata
Dentalina sp. cf. D. legumen
Dentalina sp.
Pyrulina ? sp.
Glandulina sp.
Neobulimina canadensis

Praebulimina venusae

Praebulimina sp. cf. P. kickapooensis

Eoeponidella linki
Valvulineria sp. cf. V. umbilicata
Spirillina ? sp.
Heterohelix globulosa
Globigerina aspersa
Hedbergella sp. cf. H. delrioensis
Nonionella sp. cf. N. cretacea
Gyroidina sp. cf. G. depressa
Anomalinoides sp.
Gavelinella sp. cf. G. awunensis
Gavelinella ? sp.

50 0 50
Scale in feet above base of Bearpaw Formation

FIGURE 3: RANGE CHART OF FORAMINIFERAL SPECIES FROM BEARPAW FORMATION, LETHBRIDGE AREA, ALBERTA.

beneath the Magrath Sandstone and in the interval between the Magrath and the Kipp Sandstone are significant.

The following arenaceous foraminifera appear almost suddenly at twelve feet above the base of the formation at Locality JW66-12 and are common to abundant at higher levels at the same locality:

Haplophragmoides sp. cf. H. Iinki Nauss
Verneuilinoides bearpawensis (Wickenden)
Verneuilina canadensis Cushman
Gaudryina bearpawensis Wickenden
Trochammina albertensis Wickenden

The above listed arenaceous foraminifera also occur commonly to abundantly in the shales above the Magrath sands at Locality JW66-13 and in the shales occupying at a short interval about midway between the Kipp Sandstone and the Ryegrass Sandstone at Locality JW68-1.

Haplophragmoides kirki Wickenden appears significantly at the level 56 feet above the base of the Bearpaw Shale at Locality JW66-12 and also occurs at higher horizons at the same locality and at other localities. It is one of the important components above the Magrath sands at Locality JW66-13.

Dorothia sp. is restricted in its occurrence. It is common at the interval 12-35 feet above the base of the formation at Locality JW66-12. It disappears above this horizon but reappears at a short interval of 310-336 feet above the base of the formation at Locality JW66-13 and at 478-486 feet above the base of the formation at Locality JW68-1.

Haplophragmoides sp. cf. H. rugosa Cushman occurs in

all the localities though fairly uncommon.

The following arenaceous foraminifera occur uncommonly to rarely and are restricted:

Reophax sp. cf. *R. troyeri* Tappan
Hippocrepina sp.
Haplophragmoides sp. 1
Haplophragmoides sp. 2
Haplophragmoides sp. 3
Ammobaculites sp.
Tritaxia sp.

The silty shales above the Ryegrass Sandstone is poor in microfauna.

The dominance of the arenaceous foraminifera in the Bearpaw shales suggests the generally shallow and brackish nature of the Bearpaw Sea. According to Stelck and Wall (1955, p. 27), "the dominance of almost exclusively arenaceous foraminifera .... in the Upper Cenomanian of the basal Kaskapau Shale in the Peace River county indicates a very near-shore, and probably cold and brackish environment." Probably, the occurrence at Locality JW66-12 of a few brackish water ostracods at the interval 11-12 feet above the base of the formation and also the occurrence of common-to-abundant *Haplophragmoides*, *Verneuilina*, *Verneuilinoides*, *Trochammina*, *Gaudryina*, *Ammobaculites* at the interval 12-56 feet above the base of the formation indicates a period of brackish or lagoonal environment marginal to the Bearpaw Sea. Furthermore, all the specimens belonging to these arenaceous foraminifera which were found in the above locality are highly pyritized. Many pyrite grains also occur in the washed residue. Stelck and Wall (1955, p. 28) said that "the replacement of original wall-cement of many specimens

by pyrite seems to indicate a rather toxic condition, such as might be encountered in a lagoonal environment." The basal part of the Ryegrass Sandstone at Locality JW68-1 also consists predominantly of arenaceous foraminifera and this reflects a probable lagoonal or brackish water environment.

In the preceeding paragraphs, the foraminiferal assemblage in the Bearpaw Formation has been examined mainly from the quantitative standpoint rather from the qualitative view point. At Locality JW66-12, in the intervals 56-60 feet, and 70-115 feet above the base of the formation, an association of common to abundant arenaceous foraminifera, comprising nine species, and rare to common calcareous foraminifera representing fourteen species occurs. Calcareous foraminifera associated with abundant arenaceous foraminifera in the above intervals are as follows:

Gavelinella? sp.
Neobulimina canadensis Cushman and Wickenden
Praebulimina venusae (Nauss)
Praebulimina sp. cf. P. kickapooensis (Cole)
Gyroidina sp. cf. G. depressa (Alth)
Valvulineria sp. cf. V. umbilicata (d'Orbigny)
Eoeponidella linki Wickenden
Heterohelix globulosa (Ehrenberg)

The following calcareous foraminifera also occur in the above intervals but are rare:

Quinqueloculina sphaera Nauss
Dentalina sp. cf. D. basiplanata Cushman
Dentalina sp. cf. D. legumen (Reuss)
Spirillina? sp.
Pyrulina? sp.
Glandulina sp.
Hedbergella sp. cf. H. delrioensis (Carsey)
Globigerina aspersa (Ehrenberg)

The occurrence of Heterohelix in the above assemblage is a

probable indication of an open marine environment, and the presence of Gyroidina which generally flourishes in deep marine environment suggests that the Bearpaw Sea at that period was fairly deep. The miliolids usually develop in shallow waters. In the above assemblage, very few specimens belonging to miliolids were found. Thus, the rarity of the miliolids in the above locality and intervals further suggests the relatively deep marine conditions of the Bearpaw Sea.

The buliminids and the nodosariids tolerate wide temperature and various depths under marine conditions. In temperate waters they are extensively represented both in the number of species and individuals. In the Bearpaw microfaunal assemblage the nodosariids are rare. However, the few specimens found represent six species, with each species having one to eleven individuals. The buliminids, though common in the formation, comprise only three species. Thus, the occurrence of a few specimens of nodosariids and a few species of buliminids seems to indicate that the Bearpaw Sea was fairly cold.

The occurrence of common to abundant arenaceous foraminifera associated with the calcareous foraminifera at the above locality and in the intervals mentioned seems to negate the fact that the Bearpaw Sea at that period was fairly deep. An example of deep water environment dominated by arenaceous foraminifera occurs in Toyama Bay, Japan. According to Matsuda (in Takayanagi,1960, p. 59) two types of foraminiferal assemblages were recognised in the cold water mass

called "Japan Sea peculiar water mass" - deeper than approximately 250 meters. One is the Epistominella takayanagii - Bolivina decussata - Angulogerina kokozuraensis assemblage developed on the edge of the continental shelf to the slope near the bay mouth. The other is Trochammina - Haplophragmoides assemblage developed on the continental slope and black muddy bottom occupying the main part of the bay. The former assemblage dominated by the calcareous forms develops in the sea where stratification is unstable between currents in the upper and lower water masses and circulation of bottom water is distinct. The second assemblage dominated by the arenaceous forms appears in the area which is stagnant due to stable stratification of the water. This latter condition seems to agree with the condition which might have prevailed during the deposition of the Bearpaw Shale. The occurrence of numerous ash beds in the Bearpaw Formation reflects slow deposition. Cushman (1948, p. 44) has interpreted the occurrence of arenaceous foraminifera in deep marine waters as a result of their adaptability but not preference.

Ten feet beneath the Magrath Sandstone and in the interval between the Magrath and the Kipp sands, Anomalinoides appears and becomes the dominant component of the calcareous foraminifera. Gavelinella? and Heterohelix disappear and the populations of Neobulimina and Praebulimina decline sharply.

Curiously, while most of the arenaceous foraminifera

are absent or uncommon in the silty shales forming the basal 25 feet of the Kipp Sandstone at Locality JW66-14, Anomalinoides is fairly common. The occurrence of the anomalinoids in this horizon may be due to the following causes:

i. The sea was probably relatively clean and less turbid, although discharge of clastic material from the adjacent land was fast and silting rapid. As arenaceous foraminifera generally flourish in relatively turbid and brackish water with muddy bottom conditions, the clean and less turbid water conditions would inhibit their growth but enhance the growth of some calcareous foraminifera.

ii. The occurrence of foraminifera in the silty shales at this locality might also be a mixed fauna with perhaps the Anomalinoides having been transported from elsewhere.

iii. The sea was fairly deep as is indicated by the occurrence of large smooth ammonites Placenticeras and Baculites. As such, the common occurrence of the Anomalinoides and the decline in population of arenaceous foraminifera in the silty shales would be expected.

On the basis of microfaunal association in the Bearpaw Formation in the Lethbridge area, six cycles of fluctuation of water depth may be differentiated:

i. The basal 56 feet of the formation was a period of brackish or lagoonal environment dominated entirely by arenaceous foraminifera. The sudden occurrence

of these foraminifera about twelve feet above the contact of the Bearpaw Formation with the continental Oldman Formation suggests that flooding of the Bearpaw Sea was fairly rapid.

ii. The interval between 56-115 feet above the base of the formation was probably a period of open marine connections in which arenaceous and calcareous foraminifera flourished together.

iii. Calcareous foraminifera disappeared completely from the interval 115-200 feet above the base of the formation. This interval probably represents stagnation in the environment or partial regression of the sea resulting in brackish or lagoonal environment.

iv. The recurrence of calcareous foraminifera but no planktonic forms in the interval 200-450 feet above the base of the formation indicates fairly deep but a shallower marine environment than in the second cycle. Marine pelecypods - Arctica and large ammonite - Placenticeras and Baculites occur in this horizon, further suggesting fairly deep water environment.

v. The deep water environment was probably followed by a period of another stagnation (interval 450-550 feet above the base of the formation) - brackish or lagoonal environment, in which arenaceous foraminifera still flourished but calcareous foraminifera

disappeared. Probably, regression of the Bearpaw Sea started from this period. With the deposition of the Ryegrass Sandstone and after, the regression became more rapid and the environment was not conducive to foraminifera.

vi. The Bearpaw epoch ended with the deposition of the shoreline(?) sand of the Blood Reserve Formation.

The relationship between the total number of arenaceous foraminifera species and calcareous foraminifera species in the Bearpaw Formation in the thesis area reflecting probable cycles of fluctuation of water depth is shown in Figure 4.

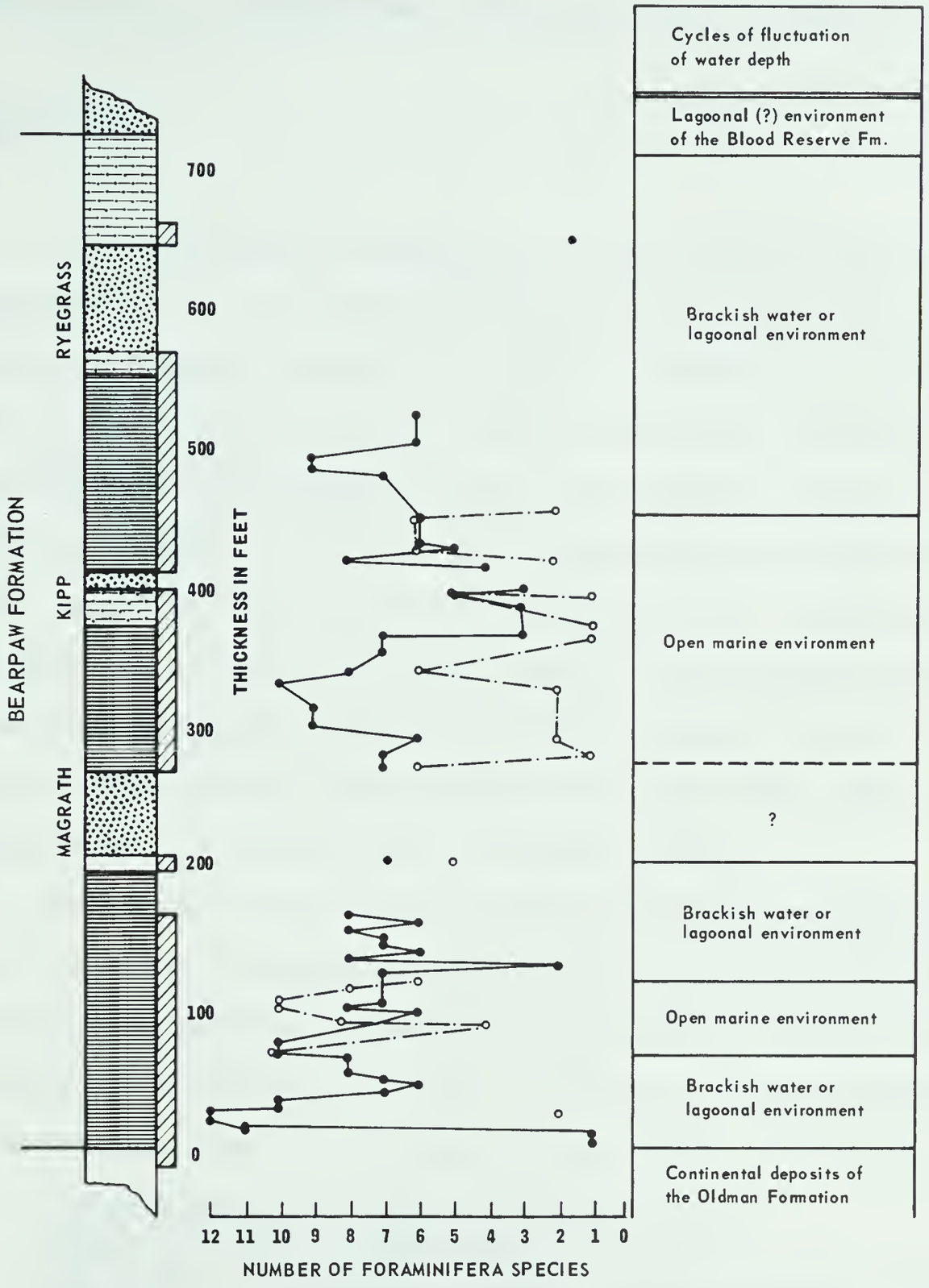


FIGURE 4: RELATIONSHIP BETWEEN THE TOTAL NUMBER OF ARENACEOUS FORAMINIFERA SPECIES AND CALCAREOUS FORAMINIFERA SPECIES IN THE SAMPLED INTERVALS OF THE BEARPAW FORMATION LETHBRIDGE AREA, TO SHOW CYCLES OF FLUCTUATION OF WATER DEPTH.

CHAPTER FOUR - MICROFAUNAL COMPARISON AND CORRELATION

Comparison

The microfaunal assemblage of the Bearpaw Formation is dominated by long-ranging arenaceous foraminifera most of which have been recorded from older formations at various localities in Alberta (Wall, 1960, 1967) and central and southwestern Saskatchewan (North and Caldwell, 1964; Caldwell and North, 1964). Generally, the calcareous foraminifera which occur in the formation are widespread. Calcareous foraminifera similar to those found in the Bearpaw Formation have been recorded from formations in northern Alaska (Bergquist, 1956; Tappan, 1960, 1962) and in the Gulf Coast Regions of the United States (Cushman, 1946).

By comparing the foraminiferal assemblage of the Bearpaw Formation in the Lethbridge area (this thesis), that of central southeastern Alberta (Given, 1969) and that of southwestern Saskatchewan (Caldwell and North, 1964) the following foraminifera seem to be common to all three localities.

Haplophragmoides kirki Wickenden
Verneuilinoides bearpawensis (Wickenden)
Dentalina basiplanata Cushman
Neobulimina canadensis Cushman and Wickenden
Heterohelix globulosa (Ehrenberg)
Globigerina aspera (Ehrenberg)
Anomalinoides sp.

The following species appear to be restricted to the Lethbridge section of the formation:

Haplophragmoides sp. cf. *H. linki* Wickenden
Haplophragmoides sp. 1

Haplophragmoides sp. 2
Haplophragmoides sp. 3
Ammobaculites sp.
Dorothia sp.
Gaudryina bearpawensis Wickenden
Verneuilina canadensis Cushman
Anomalinoides sp.
Gavelinella? sp.

The following are some of the species which are restricted to the central southeastern Alberta (Given, 1969):

Haplophragmoides rota Nauss
Haplophragmoides sp. cf. H. collyra Nauss
Haplophragmoides sp. A
Haplophragmoides sp. B
Haplophragmoides sp. C
Saccammina sp. A
Saccammina sp. B
Saccammina sp. C
Saccammina sp. D
Verneuilina sp. A
Verneuilinoides sp. A
Eoeponidella strombodes Tappan
? *Cassidella sp. A*
Anomalinoides talaria Nauss

Some of the species restricted to the formation in southwestern Saskatchewan (Caldwell and North, 1964):

Haplophragmoides excavata Cushman and Waters
Haplophragmoides calcula Cushman and Waters
Haplophragmoides glaber Cushman and Waters
Haplophragmoides inflata Graner
Bathysiphon sp.
Verneuilinoides sp.
Trochammina sp.
Anomalinoides henbesti (Plummer)
Cibicides nelsoni Berry

From the above, the genus *Haplophragmoides* Cushman appears to have more varied forms than any other genus in the Bearpaw Formation.

In the Bearpaw Formation of the Lethbridge area, the author observed that *Haplophragmoides sp. cf. H. linki* which is an important component of the faunal assemblage, shows varied forms. The coiling of this species varied from nearly

involute in some forms to almost completely evolute in other forms. Most of the specimens of this species which are not mineralized are highly compressed and have collapsed chambers, the borders of which are often seemingly thickened. Some of these forms resemble in part H. excavata Cushman and Waters or H. glabra Cushman and Waters. H. excavata and H. glabra have been recorded by Caldwell and North (1964) from the Bearpaw Formation of southwestern Saskatchewan. Given (1969, p. 56) makes tentative identification of H. rota Nauss which occurs abundantly in the formation in central southeastern Alberta. The other species of Haplophragmoides the writer records from the Lethbridge section of the Bearpaw and Given records are more or less related to each other. On the basis of these observations it appears that many of the recorded species of Haplophragmoides in the Bearpaw Formation may be related and may belong to the same stock. The differences observed in Haplophragmoides are probably reflections of local ecologic control or differences brought about by the degree of preservation. The occurrence of other groups of foraminifera restricted to the formation of the areas contrasted suggests, however, the prevalence of local ecologic differences during the Bearpaw epoch.

Correlation

In the Lethbridge section of the Bearpaw Formation microfaunal zones are not readily apparent. The assemblage

is dominated by long-ranging arenaceous foraminifera. However, the following signified species of foraminifera occur very commonly and are restricted to specific horizons of the formation:

i. Dorothia sp. restricted between 12-35 feet; 310-336 feet (rare); 478-486 feet, above the base of the formation, respectively.

ii. Gavelinella? sp. restricted between 56-115 feet above the base of the Bearpaw.

iii. Anomalinoides sp. restricted between 200-450 feet above the base of the formation.

For correlation purposes, the author has designated the occurrence of Dorothia in the basal 12-35 feet of the Lethbridge section of the Bearpaw as Dorothia sp. "Zone", the occurrence of Gavelinella?in the interval 56-115 feet above the base of the Formation as Gavelinella?sp. "Zone", and the occurrence of Anomalinoides in the interval 200-450 feet above the base of the formation as Anomalinoides sp. "Zone". The intervening intervals between these "zones" carry long-ranging arenaceous foraminifera.

From the western Saskatchewan and the southeastern Alberta sections of the Bearpaw Formation Loranger and Gleddie (1953) established five microfaunal zones and one glauconite zone. In ascending order, these zones are as follows: a Tritaxia crydermanensa Zone (260 feet thick); a Plectina smithia Zone (150 feet thick); an Anomalina sp. Zone (240 feet thick); an Ammodiscus Zone (180 feet thick);

a barren zone (40-80 feet thick); a Gyroidina sp. and Ostracoda Zone (410 feet thick). Loranger and Gleddie indicated that the Tritaxia Zone is characterized by 29 different species of microfossils of which Tritaxia, Textularia and Vernueilina are most abundant. According to these workers the basal portion of the Tritaxia zone remains constant in thickness from the Foothills to the Cypress Hills in southwestern Saskatchewan. In the Lethbridge section of the Bearpaw Formation the Dorothia sp. "Zone" carries 46 specimens of brackish water Ostracods (all found in one sample at Locality JW66-12, about 12 feet above the base of the formation), twelve species of long-ranging arenaceous foraminifera of which Verneuilinoides bearpawensis (Wickenden), Verneuilina canadensis Wickenden, Trochammina albertensis Wickenden, and Haplophragmoides cf. H. linki Wickenden occur abundantly. The occurrence of these species is persistent throughout the shaley sections of the formation. The Dorothia sp. "Zone" seems to correspond with the upper portion of the Tritaxia Zone of Loranger and Gleddie. Tritaxia and Textularia which Loranger and Gleddie said occur abundantly in this zone were never observed in the thesis area. However, six specimens of poorly preserved Tritaxia sp. were found in only one sample at the interval 135-137 feet above the base of the formation. Loranger and Gleddie pointed out that their Tritaxia zone of the Bearpaw Formation in the Bearpaw Formation in the Cypress Hills area contains faunas with a high percentage of calcareous foraminifera that may

be indicative to open marine conditions. The microfaunal association of the Dorothia sp. "Zone" of the formation in the Lethbridge area consists almost exclusively of arenaceous foraminifera. The faunal assemblage suggests a lagoonal or brackish water environment.

The Gavelinella? sp. "Zone" of the thesis area correlates with the Plectina Zone of Loranger and Gleddie. According to them, the Plectina Zone contains abundant calcareous foraminifera which indicates a deeper marine environment than that of their Tritaxia crydermanensa Zone. They pointed out that the fauna is less well developed westerly. In the Gavelinella? sp. "Zone" of this thesis area sixteen species of calcareous foraminifera including three species of planktonic foraminifera occur. Most of these calcareous foraminifera species which occur in the above zone,however, have few specimens.

The Anomalinoides sp. "Zone" of the thesis area correlates closely with the Anomalina sp. Zone of Loranger and Gleddie. According to these workers the upper half of the Anomalina sp. Zone contains Placenticeras and Baculites. In the Lethbridge section of the Bearpaw Formation Placenticeras and Baculites occur in the shales lying between and above the Kipp Sandstone Member. This horizon corresponds with the upper portion of the Anomalinoides sp. "Zone". This relationship establishes the correlation of the Anomalinoides sp. "Zone" of the Lethbridge section of the Bearpaw with the Anomalina sp. Zone of Loranger and Gleddie. How-

ever, Loranger and Gleddie said that the Anomalina sp. Zone shows a great diversification of forms both in genera and species, many of which occur in the underlying zones. They identified seven species of Anomalina two of which they said were new. In the Lethbridge section of the Bearpaw, minor morphological differences which were noted in Anomalinoides seem to reflect differences in the degree of preservation rather than genetic variation. Furthermore, there was not any significant diversification in the calcareous foraminifera in this zone. Instead, the lower Gavelinella? sp. "Zone" carries more diverse calcareous foraminifera and seems to indicate a deeper marine environment than the upper Anomalinoides sp. "Zone" of the thesis area. Aside from Anomalinoides sp. which occurs very commonly to abundantly, the other calcareous foraminifera which occur in this zone are very rare and none of the planktonic foraminifera were observed. Examination of some outcrop samples from the Lundbreck section of the Bearpaw showed that the Anomalinoides sp. "Zone" of the Lethbridge section of the formation appears to correlate with a zone (in the Lundbreck section of the Bearpaw) characterized by an association of arenaceous foraminifera and calcareous foraminifera of which Gavelinella? sp. Anomalinoides, Valvulineria and Gyroidina? are very common.

The Ammodiscus Zone and the Gyroidina and Ostracod Zone of Loranger and Gleddie seem to be absent from the Lethbridge section of the Bearpaw Formation.

Caldwell and North (1964) designated three microfaunal zones in the Bearpaw Formation of the South Saskatchewan River valley. In ascending order their zones were as follows: Gaudryina sp. Zone (150 feet thick); a barren zone (100 feet); Anomalinoides henbesti Zone (240 feet thick); Haplophragmoides excavata Zone (300 feet thick). The basal 130 feet of the formation was not sampled.

In the Lethbridge section of the Bearpaw Formation, the Dorothia sp. "Zone" and the Gavelinella? sp. "Zone" seem to correlate with a Gaudryina sp. Zone of Caldwell and North. G. bearpawensis Wickenden forms one of the important components of the foraminifera in the basal part of the Bearpaw in the thesis area.

The Anomalinoides sp. "Zone" of the thesis area correlates with the Anomalinoides henbesti Zone of Caldwell and North. The Haplophragmoides excavata Zone of Caldwell and North was not observed in the Lethbridge section of the Bearpaw. However, Haplophragmoides occurs common to abundantly above the Anomalinoides sp. "Zone" of the thesis area.

Given (1969) indicated two zones: a lower Eoeponidella strombodes Zone and an upper ?Cassidella sp. A "Zone" in the Bearpaw Formation of the Castor area, Alberta. According to Given, the Castor well upon which her zonations were based is probably the equivalent of the middle to upper half of the Manyberries Member of the Bearpaw Formation in southeastern Alberta. The Anomalinoides sp. "Zone" of the thesis area seems to correlate with the upper part of Given's Eoeponidella strombodes Zone and the lower part of the ?Cassi-

della "Zone". Eoeponidella strombodes Tappan was not observed in the Lethbridge section of the Bearpaw. Given (1969) indicated that Anomalinoides talaria (Nauss) occurs abundantly in her Eoeponidella strombodes Zone. The occurrence of A. talaria in Given's zone seems to establish the correlation between the Anomalinoides sp. "Zone" of the thesis area with Given's E. strombodes Zone. Cassidella appears to be absent from the Lethbridge section of the Bearpaw Formation.

Correlation of the microfaunal zones of the Bearpaw Formation of the thesis area with those of Given (1969), Caldwell and North (1964) and Loranger and Gleddie (1953) is shown in Figure 5.

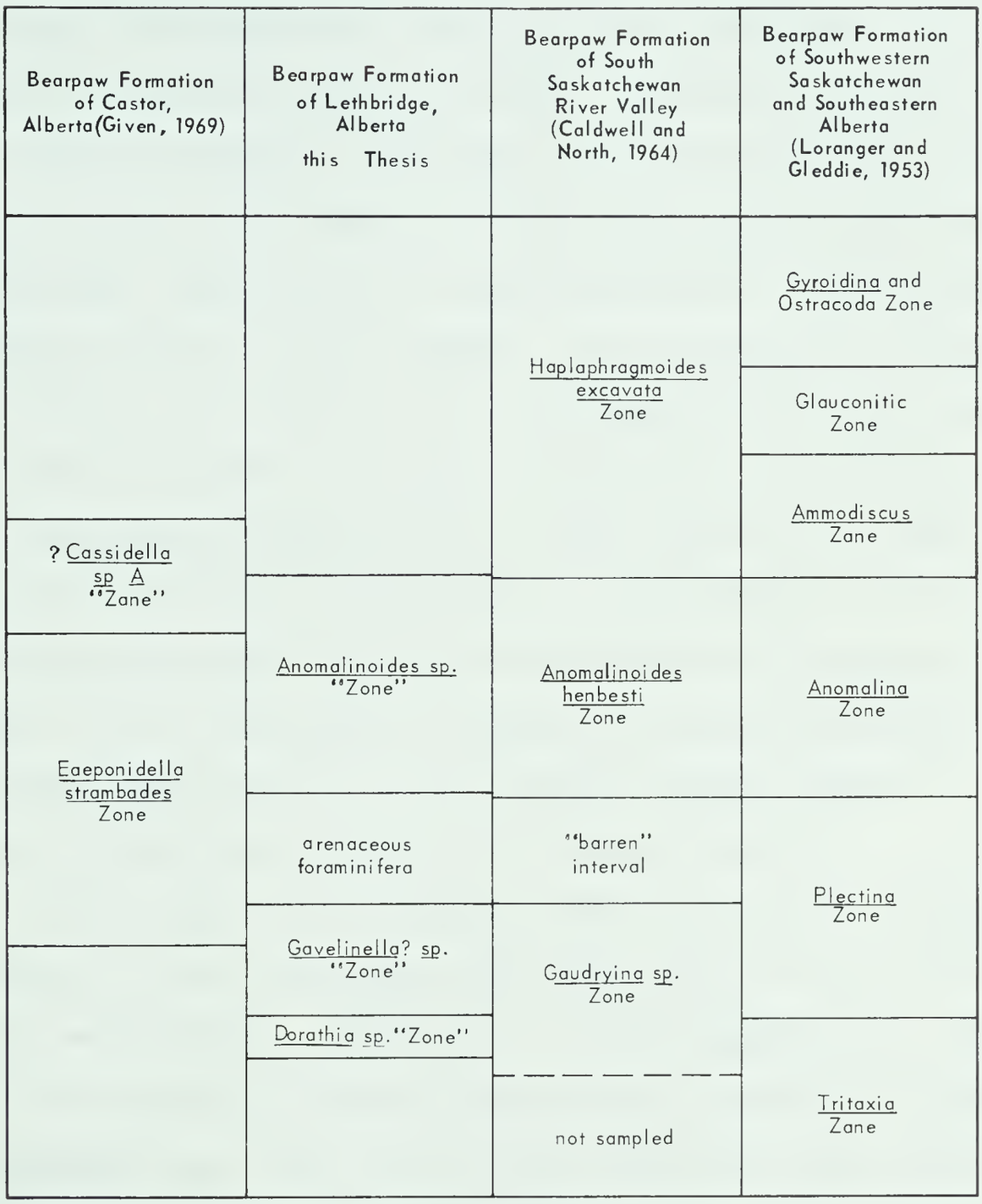


FIGURE 5: CORRELATION OF BEARPAW MICROFAUNAL ZONES IN ALBERTA AND SOUTHWESTERN SASKATCHEWAN.

CHAPTER FIVE - CONCLUSION

The microfauna of the Bearpaw Formation in the Lethbridge area consists of abundant foraminifera, a few poorly preserved ostracods, rare pieces of radiolarian(?) skeletons, scolecodonts(?) fish bones and fish teeth. Arenaceous foraminifera form the most dominant component of the foraminiferal assemblage. Most of the foraminifera are long-ranging and appear to répresent descendants of some foraminifera which inhabited previous seas of western Canada. Other species of foraminifera found in the thesis area are widespread and have been recorded in the same formation in central southeastern Alberta and southwestern Saskatchewan by other workers, and also from formations which are equivalents of the Bearpaw Formation in northern Alaska and the Gulf Coast Regions of the United States. This relationship suggests a sea which probably stretched from the Gulf Coast through western Canada to Alaska, as had been indicated by various workers.

On the basis of microfaunal association in the Bearpaw Formation in the Lethbridge area three zones have been tentatively established. These are: a basal Dorothia sp. "Zone" 12-35 feet above the base of the Bearpaw Formation; a middle Gavelinella? sp. "Zone" 56-115 feet above the base; and an upper Anomalinoides sp. "Zone" 200-450 feet above the base.

A basal Tritaxia Zone proposed by Loranger and Gleddie for the Cypress Hills section of the Bearpaw Formation appears to be absent from the Lethbridge section of the formation. The upper portion of this zone, however, correlates with the

Dorothia sp. "Zone" in the thesis area. The occurrence of this genus and its apparent absence from the formation in the areas compared seems to reflect a local ecologic control.

The Gavelinella? sp. "Zone" appears to correlate with the Plectina smithia Zone of Loranger and Gleddie and the Gaudryina sp. Zone of Caldwell and North. The genus Gavelinella? in the thesis area further suggests a variation in ecology between the two areas. The Anomalinoides sp. "Zone" of the thesis area closely correlates with the Anomalinoides henbesti Zone of Caldwell and North, the Anomalina sp. Zone of Loranger and Gleddie and the Eoeponidella strombodes Zone of Given. A similar zone characterized by abundant Gavelinella?, Anomalinoides, Gyroidina? and Valvulineria occurs in the Lundbreck section of the Bearpaw Formation.

On microfaunal evidence, six cycles of fluctuation of water depth seem to have occurred in the Lethbridge section of the Bearpaw Formation. These six cycles are as follows:

i. The basal 56 feet of the formation was probably lagoonal and with a brackish environment in which arenaceous foraminifera flourished.

ii. The above period was followed by an open marine condition (interval 56-115 feet) in which arenaceous foraminifera and calcareous foraminifera flourished together.

iii. The complete disappearance of the calcareous foraminifera at the interval 115-200 feet suggests a change of open marine conditions to brackish water

or lagoonal environment.

iv. At the interval 200-450 feet, calcareous foraminifera reappeared, but no planktonic forms, indicating fairly deep but a shallower marine environment than in the second cycle.

v. The preceeding interval 450 feet to the base of the Ryegrass Sandstone was probably a period of stagnation or a return to lagoonal environment in which the calcareous foraminifera perished while the population of the arenaceous foraminifera increased. This period probably represents the beginning of the regression of the Bearpaw Sea. With the deposition of the Ryegrass Sandstone and after, the regression became more rapid. The transitional sands and silty shales which are generally devoid of microfauna were then deposited.

vi. The Blood Reserve sand represents the sand of the retreating Bearpaw Sea to the east.

These six cycles of fluctuation of water depth in the Lethbridge section of the Bearpaw indicate varying depths of water for the Bearpaw Sea.

On faunal evidence the southwestern Saskatchewan section of the Bearpaw Formation seems to be better developed than the formation in the Lethbridge and the Lundbreck areas. This suggests that the axis of the Bearpaw basin in western Canada was probably in the vicinity of southwestern Saskatchewan.

CHAPTER SIX - FORMAL DESCRIPTIONS

Phylum PROTOZOA

Subphylum SARCODINA Schmarda, 1871

Class RETICULAREA Lankester, 1885

Subclass GRANULORETICULOSA de Saedeleer, 1934

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1896

Superfamily AMMODISCACEA Reuss, 1862

Family ASTRORHIZIDAE Brady, 1881

Genus HIPPOCREPINA Parker, 1870

HIPPOCREPINA sp.

Plate 1, figures 1, 2.

Description: Test a single chamber, vase-shaped, compressed, with weak and irregular transverse growth wrinkles visible on exterior; apertural necks present, with or without marked constrictions between them and main portions of tests; wall thick, arenaceous with medium-grained sand held together in a small amount of cement; surface rough; aperture terminal; color light grey.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen, (fig. 1)	0.88	0.50
Figured specimen, (fig. 2)	0.90	0.50

Types: The figured specimens are from Locality JW66-12, Sample 67, 164-166 feet above the base of the Bearpaw Formation.

Distribution: This species was obtained from only the above locality and sample with 18 specimens being recorded.

Remarks: Although this species shows a general similarity of shape to Hippocrepina sp., described by Wall (1967, p. 39, Plate 8, figure 6; Plate 11, figure 11), from the Wapiabi Formation in the Alberta Foothills, it is more robust, thicker-walled, and lacks the characteristic siliceous-vitreous appearance of the latter.

Family SACCAMMINIDAE Brady, 1884

Genus SACCAMMINA M. Sars, 1869

SACCAMMINA sp. cf. S. ALEXANDERI (Loeblich and Tappan)

Plate 1, figure 3.

? Proteonina alexanderi Loeblich and Tappan, 1950, Univ. of Kansas Paleontological Contrib., Protozoa, Article 3, p. 5, pl. 1, figs. 1, 2.

Proteonina sp. cf. P. alexanderi Loeblich and Tappan. Stelck and Wall, 1955, Res. Coun. Alberta Rept. 70, p. 52, pl. 1, figs. 5, 6.

? Saccammina alexanderi (Loeblich and Tappan). Eicher, 1960,

Peabody Museum of Natural History, Yale Univ., Bull. 15, p. 55, pl. 3, figs. 1, 2 -- Eicher, 1966, Contrib. Cushman Found. Foram. Res., vol. 17, pt. 1, p. 20, pl. 4, figs. 1, 2.

Saccammina sp. cf. S. alexanderi (Loeblich and Tappan).

Wall, 1967, Res. Coun. Alberta Bull. 20, p. 40, pl. 8, figs. 16, 17; pl. 14, figs. 17, 18.

Description: Test a single chamber, flask-shaped, often compressed, neck prominent, thin, elongate, slightly tapering; wall arenaceous with medium-to-coarse-grained sand, poorly sorted, often pyritized, surface rough; aperture terminal, on neck; color brown.

Dimensions:

	Length (mm.)	Width (mm.)	Neck (mm.)
Figured specimen	0.68	0.38	0.20

Types: The figured specimen is from Locality JW66-13, Sample 8, 309-314 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare. Besides the figured specimen, only two others were found at the same locality, in Sample 10, 320-325 feet above the base of the Bearpaw.

This species has been previously recorded by Stelck and Wall (1955, p. 52) from the basal portion (Cenomanian) of the Kaskapau Formation of the Peace River area. It has also been recorded from the Lower Cretaceous Kiowa Shale of Kansas, Thermopolis and Skull Creek Shales of Wyoming, and the Upper Cretaceous Carlile Shale of Colorado.

Remarks: The Bearpaw specimens seem closely similar to those from the Kaskapau Formation, as both have prominent necks and poorly sorted sand grains.

Family AMMODISCIDAE Reuss, 1862

Genus AMMODISCUS Reuss, 1862

AMMODISCUS sp. cf. A. CRETACEUS (Reuss) Cushman

Plate 1, figure 4.

Ammodiscus cretaceus (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol. Rept. Invest. 22, p. 58, pl. 1, fig. 15 -- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 17, pl. 1, fig. 35 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 130, pl. 30, figs. 1, 2 --- Graham and Church, 1963, Stanford Univ. Publ. Geol. Sci., vol. 8, no. 1, p. 17, pl. 1, fig. 17 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 11, pl. 1, figs. 4, 5.

Description: Test discoidal, deeply umbilicate, con-

sisting of small indistinct proloculus and planispirally and closely coiled tubular chamber of seven volutions, increasing uniformly in diameter; spiral suture distinct, depressed; wall finely areanaceous, smooth, usually pyritized; aperture terminal at the end of the tubular chamber.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.28	0.25	0.05

Types: The figured specimen is from Locality JW66-13, Sample 2, 272-277 feet above the base of the Bearpaw Formation, and directly above the Magrath Sandstone Member.

Distribution: This species is very rare with only two specimens being found. In addition to the figured specimen collected from directly above the Magrath Sandstone, another was obtained at the same locality from Sample 1, directly below the Magrath Sandstone or about 200-210 feet above the base of the Bearpaw.

Wickenden (1945, p. 50) recorded this species from the lower Riding Mountain beds of the eastern Saskatchewan and Manitoba plains. North and Caldwell (1964, p. 11) reported the species from the Lea Park Formation in south-central Saskatchewan. Tappan (1962, p. 130) recorded it from the Schrader Bluff Formation in Alaska. It also occurs in the

Upper Cretaceous rocks of the Gulf Coastal Region of the United States and the adjacent areas. (Cushman, 1946, p. 17).

In Europe this species has been recorded from the Gault (Albian) to the Senonian. It is said to be most characteristic of the Turonian and the lower Senonian (Cushman, 1946, p. 18).

Remarks: The Bearpaw specimens differ from the Gulf Coast specimens in being relatively smaller and in having fewer volutions of the tubular chamber. The radial creases or constrictions characteristic of the Gulf Coast specimens were not observed, but these could have been masked by pyritization.

AMMODISCUS sp.

Plate 1, figure 5.

Description: Test small, discoidal, consisting of distinct proloculus and planispirally coiled tubular chamber of five to seven volutions, increasing gradually in diameter; spiral suture distinct, depressed; wall finely arenaceous, smooth, usually pyritized; aperture terminal at the end of the tubular chamber.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.20	0.18	0.04

Types: The figured specimen is from Locality JW68-1, Sample 5, 486-489 feet above the base of the Bearpaw Formation.

Distribution: Twelve specimens of this species were collected from the above sample. The species was not found elsewhere in the present study.

Remarks: This species differs from A. cretaceus (Reuss) by its small size, relatively large and conspicuous proloculus, and fewer volutions. Because of their large proloculi, specimens of this species at this locality may represent a megalospheric population of A. cretaceus (Reuss). No specimens with smaller proloculi were observed, although microspheric forms are generally more abundant than the megalospheric ones.

Superfamily LITUOLACEA de Blainville, 1825

Family HORMOSINIDAE Haeckel, 1894

Genus REOPHAX de Montfort, 1808

REOPHAX sp. cf. R. TROYERI Tappán

Plate 1, figures 6, 7.

? Reophax troyeri Tappan, 1960, Am. Assoc. Petroleum Geol. Bull., vol. 44, no. 3, p. 291, pl. 1, figs. 10, 12 (not fig. 11) --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 133, pl. 30, figs. 11, 13 (not fig. 12).

Description: Test elongate, uniserial, straight, chambers three to six, with circular cross-section, increasing uniformly in size, final chamber much longer and produced terminally to form a neck; sutures distinct, depressed, transverse; wall finely arenaceous, usually pyritized; aperture simple, terminal, at end of neck.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen (fig. 1)	0.60	0.16
Figured specimen (fig. 2)	0.55	0.15

Types: The figured specimens are from Locality JW66-12, Sample 17, 22-24 feet above the base of the Bearpaw Formation.

Distribution: This species is fairly common at the above locality within the interval 10-60 feet above the base of the Bearpaw Formation.

Tappan (1960, p. 291) recorded this species from the Topagoruk Formation (Albian) of Alaska.

Remarks: The Bearpaw specimens are fairly similar to the Topagoruk specimens except that the Topagoruk specimens are broader and have greater length/width ratios than the Bearpaw specimens.

Family LITUOLIDAE de Blainville, 1825

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES sp. cf. H. LINKI Nauss

Plate 1, figures 8, 9.

? Haplophragmoides linki Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 339, pl. 49, figs. 7a-b.

Haplophragmoides sp. cf. H. linki Nauss. Wall, 1960, Res. Coun. Alberta Bull. 6, p. 19, pl. 4, figs. 12-15.

Description: Test planispiral, nautiloid, often compressed, involute to partially evolute, moderately umbilicate, periphery broadly rounded; chambers slightly inflated, seven to nine in ultimate whorl, gradually increasing in size; sutures distinct, often slightly thickened, straight, radial, flush to depressed; wall, finely arenaceous, usually pyritized, smooth; aperture a low arched slit at the base of terminal face, not readily visible in some specimens.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Maximum Thickness (mm.)
Figured specimen (fig. 8)	0.40	0.30	0.17
Figured specimen (fig. 9)	0.38	0.30	0.17

Types: The figured specimens are from Locality JW66-12, Sample 23, 38-40 feet above the base of the Bearpaw Formation.

Distribution: This species is common to abundant in many sampled sections of the Bearpaw Formation. Its occurrence is very persistent and it is invariably associated with Verneuilina canadensis Cushman, Verneuilinoides bearpawensis (Wickenden), Trochammina albertensis Wickenden, Gaudryina bearpawensis Wickenden, and other agglutinated foraminifera.

Nauss (1947, p. 339) recorded this species from the Lloydminster Shale. Wall (1960, p. 14) noted that the species occurs sporadically in the Kaskapau and Puskwaskau Shales.

Remarks: The Bearpaw specimens show a gradation in the nature of the coiling - from nearly involute forms to almost completely evolute forms. However, the chamber arrangement and the sutures seem to be very similar to those displayed by Nauss' types.

Wall (1960, p. 19) in his examination of a large populations of Haplophragmoides in the lower member of the Colorado Shale of central Alberta from which Nauss obtained his type material, observed "all gradations between involute individuals of H. linki 'class' and completely evolute specimens that in other respects were identical with H. linki". On this basis, the involute and evolute "varieties" of the Bearpaw specimens have been grouped together.

Most of the specimens which are not mineralized are usually poorly preserved with highly compressed, collapsed chambers, the borders of which are often seemingly thickened. Some of these forms resemble in part H. excavata Cushman and Waters or H. glabra Cushman and Waters. Most of these doubtful forms which are difficult to separate have been grouped together as unspecified Haplophragmoides.

HAPLOPHRAGMOIDES KIRKI Wickenden

Plate 1, figures 10, 11.

Haplophragmoides kirki Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 85-86, pl. 1, figs. 1a-c -- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 21, pl. 2, figs. 23a-c --- Wall, 1960, Res. Coun. Alberta Bull. 6, p. 19, pl. 3, figs. 11, 12; pl. 4, figs. 10, 11 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 13, pl. 1, fig. 8.

Description: Test small, close coiled, involute periphery broadly rounded, peripheral margin lobulate, often slightly umbilicate; chambers four and one-half to five and one-half in ultimate whorl, usually inflated; sutures distinct, straight, radial, depressed; wall finely arenaceous, usually pyritized, smooth; aperture a low arched opening at the base of the terminal face.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Maximum Thickness (mm.)
Hypotype (fig. 10)	0.35	0.33	0.22
Hypotype (fig. 11)	0.33	0.30	0.15

Types: The hypotypes are from Locality JW66-12, Sample 33, 65-67 feet above the base of the Bearpaw Formation.

Distribution: This species occurs in many sampled sections of the Bearpaw Formation. It is common in the shaley beds in the interval 56-351 feet above the base of the Bearpaw Formation. It is very rare in the lower and upper sections of the Bearpaw.

Wickenden (1932, p. 86) first described the species from exposures of Bearpaw east of Manyberries, Alberta. He noted the occurrences of the species from Bearpaw exposures on the Oldman and St. Mary Rivers near Lethbridge, and on the Crowsnest River north of Lundbreck, Alberta.

The species has also been found in the Riding Mountain beds near Millwood, Manitoba, and in well samples from the Lea Park and Pakowki in Alberta and Saskatchewan.

North and Caldwell (1964, p. 26) provisionally established two faunal zones in the Lea Park Formation in south-central Saskatchewan - an upper Quinqueloculina sphaera fauna and a lower Haplophragmoides kirki fauna. The H. kirki fauna was considered characteristic at the interval, 730-1006 feet, in the Alwinsal Sarcee 4-28 borehole, at the bottom of which the Lea Park is in contact with white-speckled clays of the top of the Colorado Group.

Wall (1960, p. 18) recorded the species from the Kaskapau and Puskwaskau Shales.

Remarks: The non-pyritized specimens of this species are usually highly compressed with collapsed chambers, colorless and hyaline. The chamber arrangements of the compressed forms are, however, very distinct and the species is easily recognised.

HAPLOPHRAGMOIDES sp. cf. H. RUGOSA Cushman and Waters

Plate 1, figure 12.

? Haplophragmoides rugosa Cushman and Waters, 1927, Cushman

Lab. Foram. Research Contr., vol. 2, pt. 4, p. 83, pl. 10, figs. 4a, b --- Cushman, 1927, Royal Soc. Canada Trans., 3rd. ser., vol. 21, sec. 4, p. 128, pl. 1, fig. 2 --- Cushman, 1931, Tennessee Div. Geol. Bull. 41, p. 17, pl. 1, figs. 3a-b --- Cushman, 1933, Cushman Lab. Foram Research Special Pub. 5, pl. 4, fig. 27 --- Cushman and Deaderick, 1944, Jour. Paleontology, vol. 18, p. 328, pl. 50 fig. 1 --- Cushman, 1946, U.S. Geol. Survey Prof. Paper 206, p. 20, pl.2, figs. 18, 19.

? Haplophragmoides rugosus Cushman and Waters. Frizzell,1954, Texas Bur. Econ. Geol. Rept. Invest. no. 22, p. 60, pl. 2, fig. 2a-b.

Description: Test medium to large size, involute, closely coiled, planispiral, compressed, often with shallow umbilicus, periphery broadly rounded, peripheral outline entire, but lobulate in large specimens; chambers about seven in the last formed whorl, inflated, increasing gradually in size; sutures fairly distinct, radial, flush with the surface, often slightly depressed in some specimens; wall coarsely arenaceous, grains angular but neatly fitted together in a small amount of cement; aperture not observed, presumably a low arched opening at the base of the terminal face; color brown.

Dimensions

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.68	0.50	0.20

Types: The figured specimen is from Locality JW66-12, Sample 17, 22-24 feet above the base of the Bearpaw Formation.

Distribution: This species occurs in many sections of the Bearpaw Formation. It is fairly common in the intervals 24-35 feet, 304-315 feet, and 384-454 feet above the base of the Bearpaw Formation.

Caldwell and North (1964, p. 147) recorded this species from the Bearpaw Formation in southwestern Saskatchewan.

The species also occurs in the Navarro and Taylor Groups of the Gulf Coastal Region of the United States (Cushman 1946, p. 21).

Remarks: Most of the Bearpaw specimens are highly compressed and poorly preserved. They differ from the Gulf Coast specimens in having poorly sorted grains.

HAPLOPHRAGMOIDES sp. 1.

Plate 1, figure 13.

Description: Test medium to large size, planispiral, symmetrical, partly evolute with portion of penultimate whorl visible on one side of the test, periphery rounded, peripheral margin lobulate; chambers in penultimate whorl small and closely coiled, chambers in ultimate whorl seven in number, inflated, increasing rapidly in size with the last three chambers tending to flare; sutures distinct, radial, straight, depressed; wall finely agglutinated, usually pyritized; aperture a low slit-opening at the base of the terminal face, obscured in many specimens.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.63	0.50	0.38

Types: The figured specimen is from Locality JW66-12, Sample 15, 17-19 feet above the base of the Bearpaw Formation.

Distribution: This species is rare. Besides the figured specimen, 10 were obtained at the same locality from Sample 45, 102-104 feet above the base of the Bearpaw Formation.

Remarks: This species is closely similar to H. fraseri Wickenden described from the Bearpaw Formation, except that the last whorl has only about seven chambers instead of nine or ten.

HAPLOPHRAGMOIDES sp. 2

Plate 1, figure 14.

Description: Test medium size, planispiral, involute, compressed, periphery rounded, slightly umbilicate; chambers indistinct, five or six in the ultimate whorl, wedge-shaped, gradually increasing in size; sutures not very distinct, oblique to tangential to umbilicus, straight, slightly depressed; wall composed of coarse angular quartz fragments of about 0.15 mm. in size held together in a very small amount of cement, surface very rough; aperture obscured; color brownish to colorless.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.50	0.35	0.15

Types: The figured specimen is from Locality JW66-12, Sample 15, 17-19 feet above the base of the Bearpaw Formation.

Distribution: This species is rare. Only seven specimens were found within the interval 13-30 feet above the base of the Bearpaw Formation.

Remarks: This species differs from H. rugosa Cushman and Waters by its relatively smaller size, the oblique sutures and the coarser quartz fragments. It differs from H. calcula

Cushman and Waters by its much smaller size and lesser number of chambers.

HAPLOPHRAGMOIDES sp. 3

Plate 1, figures 15, 16.

Description. Test medium to large, planispiral, scaphithoid, involute, somewhat umbonate, periphery sub-acute, rounded, peripheral margin entire to slightly lobulate; chambers seven in the last whorl, wedge-shaped, increasing uniformly in size; sutures distinct, thickened towards the center giving star-like appearance, flush with the surface; wall finely arenaceous with a lot of amorphous silica, usually pyritized, smooth; aperture a triangular shaped arch at the terminal face.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Maximum Thickness (mm.)
Figured specimen (fig. 15)	0.53	0.40	0.14
Figured specimen (fig. 16)	0.70	0.48	0.15

Types: The figured specimens are from Locality JW66-13. Specimen (fig. 15) is from Sample 4, 288-293 feet above the base of the Bearpaw Formation and specimen (fig. 16) is from Sample 10, 320-325 feet above the base.

Distribution: Only the figured specimens were found in the Bearpaw Formation.

Remarks: This species differs from H. linki Nauss in being scaphitoid in shape, somewhat umbonate and with distinctly thickened sutures.

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES sp.

Plate 1, figure 17.

Description: Test small to medium size, slightly tapering, rounded cross section; early portion close coiled, of about four to five indistinct chambers; later portion uniserial, of three to five chambers increasing gradually in size as added; sutures indistinct, radial in coiled portion, distinct, depressed and transverse in uniserial portion; wall finely arenaceous, usually pyritized, surface rough; aperture terminal, slightly produced, obscured.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	0.75	0.18

Types: The figured specimen is from Locality JW66-13, Sample 10, 320-325 feet above the base of the Bearpaw Formation.

Distribution: Although this species is generally rare, it is fairly common in two short intervals at two localities. Sixteen specimens were obtained from Locality JW66-12, Samples 13 to 17, from the interval 12-24 feet above the base of the Bearpaw and 47 specimens were collected at Locality JW66-13, Samples 8 to 10, from the interval 315-325 feet above the base of the Bearpaw Formation.

Remarks: This species differs from Ammobaculites fragmentarius Cushman in being relatively smaller and in having a wall composed of finer grained materials rather than the coarse sand in flat flakes which is characteristic of A. fragmentarius Cushman.

However, the Bearpaw specimens seem to be more closely related to Ammobaculites fragmentarius Cushman as described by Tappan (1962, p. 136) from the Topagoruk Formation of Alaska.

Tappan (1962, p. 137) has indicated that Ammobaculites fragmentarius has variable characters as regards to the wall texture. In sandy strata it may be extremely coarse-textured, and have little apparent cement. In silty or shaley beds it is finer grained and may have a smoothly finished surface. Tappan further suggested that A. fragmentarius, A. humei Nauss and A. tyrrelli Nauss are separated only on minor variations and may probably represent only a single species.

Thus, the close resemblance of the Bearpaw specimens with the Topagoruk specimens seem to indicate the same species - A. fragmentarius Cushman.

Family TROCHAMMINIDAE Schwager, 1877

Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA ALBERTENSIS Wickenden

Plate 1, figure 18.

Trochammina albertensis Wickenden, 1932, Trans. Roy, Soc. Can., 3rd ser., vol. 26, sec. 4, p. 90, pl. 1, figs. 9a-c --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 50, pl. 15, fig. 7 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 152, pl. 39, figs. 13, 14.

Description: Test trochoid, nearly circular in dorsal view, conical in peripheral view, deeply umbilicate; chambers distinct, inflated, arranged in three whorls with five chambers in the last formed whorl; sutures distinct, depressed, strongly oblique; wall finely and evenly arenaceous with much cement, smooth, usually pyritized; aperture not observed, masked by pyritization, presumably an arched opening on the inner margin of the ventral side of the last-formed chamber.

Dimensions:

	Diameter (mm.)	Thickness (mm.)
Hypotype	0.35	0.23

Types: The hypotype is from Locality JW66-12, Sample 17, 22-24 feet above the base of the Bearpaw Formation.

Distribution: This species occurs very commonly within the interval 12 feet to 35 feet above the base of the Bearpaw at Locality JW66-12. The population decreases abruptly above this interval but increases again at higher levels.

Wickenden (1932, p. 90) described the holotype from exposures of the Bearpaw on the Oldman River near Lethbridge.

Tappan (1962, p. 153) reported it from the Barrow Trail member of the Schrader Bluff Formation, Alaska.

Remarks: There is a slight variation in the chamber arrangement of this species. The holotype as described by Wickenden (1932) has a high spire and is conical, with the chambers in the initial whorl much smaller. The paratypes have slightly larger chambers in the initial whorls thus making the test dome-shaped rather than conical.

The non-pyritized specimens are usually compressed with chambers in early whorls being reddish brown and those in

the final whorl hyaline and yellowish brown.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Genus VERNEUILINA d'Orbigny, 1839

VERNEUILINA CANADENSIS Cushman

Plate 2, figure 2.

Verneuilina canadensis Cushman, 1927, Trans. Roy. Soc. Can., 3rd ser., vol. 21, sec. 4, p. 131-132, pl. 1, figs. 11 --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 31, pl. 7, figs. 2, 3 --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 74, pl. 1, figs. 14, 15.

? Verneuilina cf. canadensis Cushman, North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 15, pl. 2, figs. 4a-b.

Description: Test triserial, tapering, triangular in cross-section with edges subrounded, the sides concave resulting from depressions along the contacts of the vertical series; chambers inflated, increasing gradually in size, six to eight whorls in most specimens; sutures distinct, depressed; wall finely arenaceous with fair amount of cement, smooth, usually pyritized; aperture an arched opening on the inner side of the last chamber.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype	0.77	0.38

Types: The hypotype is from Locality JW68-1, Sample 3, 479 feet above the base of the Bearpaw Formation.

Distribution: This species is very common to abundant in all the shaley beds of the Bearpaw Formation. It occurs usually in association with Verneuilinoides bearpawensis (Wickenden), Gaudryina bearpawensis Wickenden, and Haplophragmoides.

The species has been recorded in many Cretaceous formations in Western Canada. Cushman (1927, p. 131) described it from the Lloyminster Shale at Alberta. North and Caldwell (1964, p. 15) reported V. sp. cf. V. canadensis from the basal part of the Bearpaw Formation. Wall (1967, p. 74) observed it in the Sunkay Member of the Blackstone Formation in the Foothills, in the Colorado Shale in central Alberta, and in the lower part of the Shaftesbury Formation of the Peace River Plains region of northern Alberta.

Eicher (1960, 1965) reported it in the Shell Creek Shale of Wyoming and in the Graneros Shale Colorado.

Remarks: The Bearpaw specimens are closely similar to

the forms recorded elsewhere in the Upper Cretaceous rocks of Western Canada.

Genus VERNEUILINOIDES Loeblich and Tappan, 1949

VERNEUILINOIDES BEARPAWENSIS (Wickenden)

Plate 2, figure 1.

Verneuilina bearpawensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 87, pl. 1, fig. 8 -- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 31, pl. 7, figs. 4-6.

Verneuilinoides bearpawensis (Wickenden). Wall, 1960, Res. Coun. Alberta Bull. 6, p. 22-23, pl. 4, figs. 20-21 --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 75-76, pl. 4, figs. 31-34; pl. 5, figs. 21; pl. 14, figs. 13-15.

? Verneuilinoides cf. bearpawensis (Wickenden), North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 15-16, pl. 2, figs. 3a-b.

Description: Test elongate, tapering, nearly circular in cross-section in undeformed forms; adult test consists of five convolutions of three chambers each, arranged in a Buliminella-like spiral; chambers in early whorl very small, inflated, rapidly increasing in size; sutures distinct, depressed; wall finely arenaceous, usually pyritized; aperture an arched opening at the inner margin of the last-formed chamber, obscure in most specimens.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype	0.74	0.28

Types: The hypotype is from Locality JW66-13, Sample 4, 288-293 feet above the base of the Bearpaw Formation.

Distribution: This species is the most dominant component of the Bearpaw microfauna. It is common to abundant in the shaley section beginning 12 feet above the base of the Bearpaw Formation.

Wickenden (1932) described the holotype from an exposure of the Bearpaw shale on the Oldman River near Lethbridge.

North and Caldwell (1964, p. 15) reported V. sp. cf. V. bearpawensis from the upper part of the Lea Park Formation. Wall (1960, p. 22) recorded it from the lower part of the Puskwaskau Formation along the Lower Smoky River in the Plains region of northwestern Alberta. In the Foothills of central Alberta, Wall (1967, p. 75) indicated that the range of this species extends from the Opabin Member of the Blackstone Formation to the Nomad Member of the Wapiabi Formation (Turonian to Campanian).

Remarks: The only noticeable variation in the material examined is in the number of chambers.

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA BEARPAWENSIS Wickenden

Plate 2, figures 3-5.

Gaudryina bearpawensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, pl. 1, fig. 7.

Description: Test elongate, early two thirds portion triserial with triangular cross section, strongly tapering towards the initial chambers, later one third often twisted, biserial, with subcircular cross section in undeformed forms, slightly tapering towards the final chamber; chambers distinct, subglobular, triserial portion with three rows of six to eight chambers each, biserial portion with two to six chambers only; sutures distinct, depressed, slightly curved; wall finely arenaceous with much cement, usually pyritized; aperture a broad semi-circular arch at the base of the last-formed chamber, color brownish grey.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype (fig. 5)	0.65	0.21
Hypotype (fig. 3)	0.55	0.20
Hypotype (fig. 4)	0.75	0.25

Types: The hypotype (fig. 5) is from Locality JW66-12, Sample 32, 63-65 feet above the base of the Bearpaw Formation.

The hypotypes (figs. 3 and 4) are from Locality JW68-1, Sample 3, 479 feet above the base at the Bearpaw.

Distribution: In the shaley beds beneath the Magrath Sandstone and the Kipp Sandstone, the species is common to abundant and occurs associated with Verneuilina canadensis Cushman, Verneuilinoides bearpawensis (Wickenden), and Haplophragmoides. It is almost absent above the Kipp Sandstone at Locality JW66-14, but reappears in the interval 470-503 feet above the base of the Bearpaw at Locality JW68-1 in Samples 1 to 8.

Wickenden (1932, p. 88) first recorded this species from the Bearpaw exposures on the Oldman and St. Mary Rivers near Lethbridge, and also from the Bearpaw exposures on the Crowsnest River, just north of Lundbreck, Alberta.

Remarks: There is a certain amount of variation in the number of chambers both in the triserial and biserial portions of the test. The number of chambers in the biserial portion varies from two to six. Many of the specimens seem to show a certain degree of transition in the chamber arrangements between Verneuilina canadensis Cushman and Gaudryina bearpawensis Wickenden.

Genus DOROTHIA Plummer, 1931

DOROTHIA sp.

Plate 2, figure 6.

Description: Test elongate, initial portion tapering to a blunt point, earliest portion obscure with about four or more chambers per whorl, intermediate portion indistinct, triserial, of about one or two whorls, latest portion biserial, of five to six pairs of interlocking chambers comprising two-thirds to three-quarters of length of the test; chambers inflated and increasing uniformly in size in biserial portion; sutures indistinct in early portion, distinct in intermediate and biserial portion, depressed and transverse; wall finely arenaceous, usually pyritized, surface smooth; aperture a large semicircular opening at the base of the last-formed chamber; color greyish white in non-pyritized specimens.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	0.42	0.13

Types: The figured specimen is from Locality JW66-12, Sample 15, 17-19 feet above the base of the Bearpaw Formation.

Distribution: This species is common at Locality JW66-12, in Samples 13 to 23, 12-35 feet above the base of the Bearpaw Formation, where a total of 247 specimens was obtained. It

is absent in the interval 35-310 feet above the base, but reappears in the interval 310-336 feet above the base, at Locality JW66-13, in Samples 10 to 12, and at 479 feet above the base at Locality JW68-1, in Sample 3.

Remarks: This species is fairly closely related to Dorothia glabrata Cushman in the general shape of the test. However, the Bearpaw specimens have a blunt initial portion and the sutures are slightly inclined. It is less robust than Dorothia smokyensis Wall.

Genus TRITAXIA Reuss, 1860

TRITAXIA sp.

Plate 2, figure 7.

Description: Test elongate, triserial, tapering; somewhat triangular in cross section, test drawn out to a neck; chambers numerous, indistinct; sutures not very distinct, slightly depressed; wall finely arenaceous, surface rough, aperture terminal, at the end of the neck on the last-formed chamber; color grayish brown.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	0.50	0.22

Types: The figured specimen is from Locality JW66-12, Sample 57, 134-136 feet above the base of the Bearpaw Formation.

Distribution: Six specimens of this species were obtained from the above sample. It was not observed elsewhere.

Remarks: The specimens are too poorly preserved to make any comparisons possible.

Suborder MILIOLINA Delage and Herouard, 1896

Superfamily MILIOLACEA Ehrenberg, 1839

Family MILIOLIDAE Ehrenberg, 1839

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA SPHAERA Nauss

Plate 2, figure 8.

Quinqueloculina sphaera Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 340, pl. 48, figs. 14a-c --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 157, pl. 37, figs. 6a-c --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 17, pl. 3, figs. 1a-c --- Wall, 1967, Res. Coun. Alberta, Bull. 20, p. 86, pl. 6, figs. 16-18.

Description: Test small, sub-circular in side view, inflated, periphery rounded; chambers arranged in quinqueloculine plan, four visible from one side, three on the other side; sutures distinct, depressed; wall calcareous, porcellaneous, imperforate, surface smooth; aperture a slit at the end of the last-formed chamber, restricted and obscure; colorless or white.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype	0.20	0.15

Types: The hypotype is from Locality JW66-12, Sample 43, 94-99 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare. Only four specimens were found in Samples JW66-12-41 and JW66-12-43, section 95-97 feet above the base of the Bearpaw.

This species has been recorded both from the Wapiabi and Lea Park Formations. Nauss (1947, p. 340) described it from the lower 40 feet of the Lea Park Shale in the Vermilion area. North and Caldwell (1964, p. 17) considered it a guide fossil for the microfauna from the middle portion of the Lea Park in south-central Saskatchewan. Wall (1967, p. 87) found eight representatives of this species from the Muskiki Member and one from the overlying Marshybank Member

of the Wapiabi Formation on Thistle Creek. One specimen was also found from the Cardium Formation on Cripple Creek.

Remarks: The Bearpaw specimens are sub-circular to oblong in side view. The chambers are distinct but the aperture is restricted and obscure.

Suborder ROTALIINA Delage and Herouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Genus LENTICULINA Lamarck, 1803

LENTICULINA sp. cf. L. ALEXANDERI (Sandidge)

Plate 2, figure 9.

? Robulus alexanderi Sandidge. Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 55, pl. 18, fig. 9.

Description: Test planispiral, somewhat elongate, biconvex, peripheral margin subacute; apertural face triangular, flat; chambers six in number, uniformly increasing in size; sutures distinct, flush with surface, broadly curving away from aperture; wall calcareous, smooth; aperture at the peripheral angle, radiate, with lower part extending as a slit into the apertural face.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.35	0.29	0.12

Types: The figured specimen is from Locality JW66-14, Sample 4, 379 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare with only the figured specimen being found.

Cushman (1946, p. 55) recorded the species from the Upper Cretaceous Ripley Formation of Alabama.

Remarks: The Bearpaw specimen differs from the Ripley Formation specimens in having only six chambers instead of eight.

LENTICULINA sp.

Plate 2, figure 10.

Description: Test large, planispiral, biconvex, peripheral margin subacute, apertural face triangular, narrow, flat; chambers indistinct, about eight increasing gradually in size; sutures flush with surface, broadly curving backwards; wall calcareous, perforate, smooth; aperture not

observed, apparently at the peripheral angle; color yellowish.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.58	0.49	0.27

Types: The figured specimen is from Locality JW66-14, Sample 4, 379 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare with only two specimens being found. In addition to the figured specimen, another was obtained from Locality JW66-13, Sample 2, 272-277 feet above the base of the Bearpaw Formation.

Remarks: This species differs from L. alexanderi by its large size, acute peripheral margin and the absence of a slit in the apertural face.

Genus NODOSARIA Lamarck, 1812

NODOSARIA sp.

Plate 2, figure 11.

Description: Test elongate, tapering to a pointed initial end; chambers very distinct, subglobular; sutures distinct, transverse, depressed; wall calcareous, ornamented

with 14 parallel longitudinal ridges; aperture terminal, possibly radiate; color yellowish.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	1.25	0.25

Types: The figured specimen is from Locality JW66-14, Sample 12, 431-436 feet above the base of the Bearpaw Formation.

Distribution: The species is very rare with only the figured specimen being found.

Remarks: The specimen is broken and incomplete.

Genus DENTALINA Risso, 1826

DENTALINA sp. cf. D. BASIPLANATA Cushman, 1938

Plate 2, figure 12.

Dentalina basiplanata Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 68, figs. 1-6 --- Frizzell, 1954, Texas Bur. Econ. Geol. Rept. Invest. 22, p. 86, pl. 9, figs. 32-33 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 174, pl. 45, fig. 17 --- Graham and Church, 1963, p. 27-28, pl. 2, fig. 11.

Description: Test elongate, slightly tapering to an initial blunt end, slightly curved; chambers distinct, twelve in number, earlier chambers low and broad, not inflated, later chambers becoming more elongated and slightly inflated; sutures distinct, oblique, flush with the surface in the earlier portion, becoming more transverse and more depressed in the later portion; wall calcareous, smooth; aperture terminal, radiate.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	2.0	0.33

Types: The figured specimen is from Locality JW66-13, Sample 10, 320-325 feet above the base of the Bearpaw Formation.

Distribution: Thirteen specimens were found at Locality JW66-12, with two specimens from Sample 29, 56-58 feet above the base of the Bearpaw, and a total of 11 specimens from Samples 41 to 49 from the interval 90-115 feet above the base of the formation. The species also occurs sporadically in a few samples at Localities JW66-13 and JW66-14. It is generally associated with other calcareous foraminifera.

Caldwell and North (1964, p. 148) recorded this species from the Bearpaw Formation in southwestern Saskatchewan.

The species has been reported in the Lea Park Formation in south-central Saskatchewan (North and Caldwell, 1964, p. 18); in the Rogers Creek Member of the Schrader Bluff Formation in Alaska (Tappan, 1962, p. 174); in the Navarro and Taylor Groups of Texas, and equivalent strata throughout the Gulf Coast (Cushman, 1946, p. 68).

Remarks: This species is similar to the recorded forms from other localities in the general shape of the test. However, the initial coiled portion which is characteristic of the other described forms was not observed in the Bearpaw specimens.

DENTALINA sp. cf. D. LEGUMEN (Reuss)

Plate 2, figure 14.

? Dentalina legumen (Reuss). Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 65, pl. 23, fig. 1, 2 --- Graham and Church, 1963, Stanford Univ. Publ. Geol. Sci., vol. 8, no. 1, p. 29, pl. 2, figs. 14-16 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Geol. Div. Rept. no. 5, p. 19, pl. 3, fig. 8.

Description: Test elongate, tapering, slightly curved, periphery rounded, chambers about ten in adult form, very slightly inflated; sutures distinct, oblique, almost flush

with the surface in the later portion; wall calcareous, with numerous faint longitudinal striations; aperature terminal, produced, radiate; color yellowish.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	1.70	0.25

Types: The figured specimen is from Locality JW66-12, Sample 37, 75-77 feet above the base of the Bearpaw.

Distribution. Ten specimens of this species were found at the above Locality with three specimens in Sample 37, four in Sample 39 at 81-83 feet above the base of the Bearpaw, and one in Sample 45, 102-104 feet above the base of the formation.

Cushman (1946, p. 65) recorded this species from the Navarro, Taylor and Austin Groups of the Gulf Coastal Region of the United States. North and Caldwell (1964, p. 19) observed it from the Lea Park Formation of south-central Saskatchewan.

Remarks: This species is similar to D. legumen Reuss in the sutures being oblique, but differs from it in having more chambers and in the wall being ornamented with faint longitudinal striations.

DENTALINA sp.

Plate 2, figure 14.

Description: Test elongate, slightly tapering, broadly curved; chambers distinct, nine in number, early chambers short and broad, fairly uniformly increasing in length as added; sutures distinct, limbate in the earlier portion of the test, impressed in the later portion, oblique throughout; wall calcareous, smooth; aperture terminal, radiate.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	1.63	0.20

Types: The figured specimen is from Locality JW66-12, Sample 45, 102-104 feet above the base of the Bearpaw Formation.

Distribution: Only the figured specimen was found in the Bearpaw Formation.

Remarks: This specimen is similar to D. legumen (Reuss), in the obliquity of the sutures, but differs from it in having limbate sutures in the earlier portion of the test.

Family POLYMORPHINIDAE d'Orbigny, 1839

Genus PYRULINA d'Orbigny, 1839

PYRULINA? sp.

Plate 2, figure 15.

Description: Test elongate, somewhat fusiform with the greatest diameter about one third from the initial portion of the test; chambers elongate, somewhat overlapping, obscured; sutures not very distinct, obscured by deformation; wall calcareous, hyaline, smooth; aperture terminal, radiate, produced on a short neck; color yellowish.

Dimension:

	Length (mm.)	Width (mm.)
Figured specimen	0.63	0.25

Types: The figured specimen is from Locality JW66-12, Sample 39, 81-83 feet above the base of the Bearpaw Formation.

Distribution: Only the figured specimen was found in the Bearpaw Formation.

Family GLANDULINA Reuss, 1860

Genus GLANDULINA d'Orbigny, 1839

GLANDULINA sp.

Plate 2, figure 16.

Description: Test medium size, fusiform, greatest width about the middle of the test, tapering to a sharply pointed initial end and bluntly pointed apertural end; chambers few, biserial to uniserial, much overlapping; sutures somewhat indistinct, flush; wall calcareous, hyaline smooth, perforate; aperture terminal, radiate, color grey.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	0.63	0.20

Types: The figured specimen is from Locality JW66-13, Sample 1, 200-210 feet above the base of the Bearpaw Formation.

Distribution: The species is very rare. One other specimen was found along with the figured specimen in the above sample.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Genus NEOBULIMINA Cushman and Wickenden, 1928

NEOBULIMINA CANADENSIS Cushman and Wickenden

Plate 2, figures 17, 18.

Neobulimina canadensis Cushman and Wickenden, 1928, Cushman Lab. Foram, Research, Contr., vol. 4, p. 13, pl. 1,

figs. 1-2 --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 125, pl. 52, figs. 11, 12 --- Nauss, 1947, Jour. Paleontology, vol., 21, no. 4, p. 340, pl. 48, figs. 5a-b --- Frizzell, 1954, Bur. Econ. Geol. Rept. Invest. 22, p. 116, pl. 17, fig. 11 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 185, pl. 48, figs. 18-27.

Description: Test small, elongate, tapering, early portion of test triserial of about three whorls comprising from about one quarter to about one third the length of test; later portion biserial of three to four whorls; chambers in triserial portion from nine to sixteen, inflated, subglobular; chambers in biserial portion five to seven, slightly more inflated; sutures distinct, depressed; wall calcareous, hyaline, perforate, smooth, aperture loop-shaped in the inner face of the terminal chamber; color yellowish.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype (fig. 18)	0.30	0.13
Hypotype (fig. 17)	0.25	0.12

Types: The hypotypes are from Locality JW66-12, Sample 37, 75-77 feet above the base of the Bearpaw Formation.

Distribution: This species is common in the lower part

of the Bearpaw at the above Locality. Thirty-six specimens were found in Sample 29, 56-58 feet above the base of the formation, and a total of 605 specimens in Samples 35 to 49, from the interval 70-115 feet above the base of the Bearpaw. The species is rare at Localities JW66-13 and JW66-14 and absent at the other localities.

The species is characteristically associated with Praebulimina venusae (Nauss), Praebulimina sp. cf. P. kickapooenis (Cole), Gavelinella? sp., Anomalinoides sp. and with less common calcareous foraminifera.

Caldwell and North (1964, p. 148) reported this species in association with the above mentioned calcareous foraminifera in the Bearpaw Formation in southwestern Saskatchewan. It has also been recorded in the Lea Park Formation of the Vermilion Area, Alberta, (Nauss, 1947, p. 340). Cushman (1946, p. 125) reported it from the Navarro, Taylor and Austin Groups of the Gulf Coastal Regions of the United States. Tappan (1962, p. 185) recorded it from the Schrader Bluff Formation of Alaska.

The species was originally described from the Upper Cretaceous Bearpaw Shale of the Lethbridge area, Alberta.

Genus PRAEBULIMINA Hofker, 1953

PRAEBULIMINA VENUSAE (Nauss)

Plate 2, figure 19.

Bulimina venusae Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 334-335, pl. 48, fig. 10.

Praebulimina venusae (Nauss). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 188, pl. 49, figs. 19-21 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 21, pl. 3, figs. 13a-b --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 94, pl. 15, figs. 19-22.

Description: Test small, tapering, triserial, of four to five whorls; chambers of earlier portion low, chambers of the last one to two whorls inflated and increasing rapidly in height; sutures distinct, depressed; wall calcareous, hyaline perforate, smooth; aperture a comma-shaped opening on the inner face of the last chamber; color yellowish.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype	0.32	0.17

Types: The hypotype is from Locality JW66-12, Sample 37, 75-77 feet above the base of the Bearpaw Formation.

Distribution: At the above Locality, 52 specimens of

this species were found in Sample 29, 56-58 feet above the base of the Bearpaw, and a total of 258 in Samples 35 to 49 from the interval 70-115 feet above the base of the formation. It is rare at Localities JW66-13 and JW66-14, and absent at the other localities.

Nauss (1947, p. 334-335) described the species from the upper Lea Park Shale and the Vanesti tongue of the Belly River Formation. North and Caldwell (1964, p. 12) recorded the species from the upper Lea Park Formation in south-central Saskatchewan. The species also occurs in the Lea Park and the Bearpaw Formations of southwestern Saskatchewan (Caldwell and North, 1964, p. 146; p. 148). Wall (1967, p. 94) reported six specimens of this species from the Nomad Member of the Wapiabi Formation in the Alberta Foothills. Tappan (1962, p. 188) reported the species from the Schrader Bluff Formation in Alaska.

PRAEBULIMINA sp. cf. P. KICKAPOOENSIS (Cole)

Plate 2, figure 20.

? Bulimina kickapooensis Cole, 1938, Florida Dept. Cons. Geol. Bull. 16, p. 45, pl. 3, fig. 5 --- Cushman and Hedberg, 1941, Cushman Lab. Foram Res. Contr., vol. 17, p. 94, pl. 22, figs. 28a-c --- Cushman and Deaderick, 1944, Jour. Paleont., vol. 18, no. 4, p. 337, pl. 53,

fig. 7 --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 123, pl. 51, figs. 11, 12, 14; pl. 66, fig. 12.

Bulimina kickapooensis Cole var. kickapooensis Cole.

Frizzell, 1954, Texas Bur. Econ. Geol. Rept. Invest. 22, p. 115, pl. 16, figs. 51-52.

? Praebulimina kickapooensis (Cole). Graham and Church, 1963, Stanford Univ. Publ., Geol. Sci., vol. 8, no. 1, p. 54, figs. 4-7.

Description: Test small, triserial, slightly twisted, tapering to an initial blunt end, about two and one half times as long as wide; five whorls of chambers, interlocking, angled, inflated, increasing uniformly in size as added; sutures distinct, depressed; wall calcareous, hyaline, perforate, smooth; aperture loop-shaped near the apex of the last-formed chamber; color yellowish brown.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	0.33	0.15

Types: The figured specimen is from Locality JW66-12, Sample 41, 92-94 feet above the base of the Bearpaw Formation.

Distribution: This species is common at the above locality. Six specimens were found in Sample 29, 56-58 feet above the base of the Bearpaw and a total of 147 specimens

in Samples 35 to 49 from the interval 70-115 feet above the base of the formation. It is present but rare in Localities JW66-13 and JW66-14.

Caldwell and North (1967, p. 148) observed the species in the Anomalinoides henbesti faunal zone, Middle Clay Member, of the Bearpaw Formation in southwestern Saskatchewan.

The species also occurs widely in the Navarro, Taylor and Austin Groups of the Gulf Coast Region of the United States.

Remarks: The Bearpaw specimens have more inflated chambers, with correspondingly more depressed sutures and the apertures are less apically placed.

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838

Genus EOEPONIDELLA Wickenden, 1949

EOEPONIDELLA LINKI Wickenden

Plate 3, figure 1.

Eoeponidella linki Wickenden, 1949, Trans. Roy. Soc. Can., 3rd ser., vol. 42 (1948), sec. 4, p. 81-82, figs. 1a-c --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 195, pl. 54, figs. 9, 10.

? Eoeponidella sp. cf. E. linki Wickenden. Wall, 1967, Res. Coun. Alberta Bull. 20, p. 98, pl. 15, figs. 34-39.

Description: Test small, planoconvex, spiral side convex, umbilical side slightly concave, periphery rounded; chambers arranged in two to three whorls, all visible on the spiral side, only those of last-formed whorl and some supplementary ones forming an inner whorl are visible on the umbilical side; five to six chambers in the last-formed whorl, with four to five supplementary stellar chambers; sutures distinct, slightly depressed, radial to slightly curved; wall calcareous, perforate, smooth; aperture a rounded arch on the ventral side of the last-formed chamber; color brownish.

Dimensions:

	Diameter (mm.)	Thickness (mm.)
Hypotype	0.25	0.08

Types: The hypotype is from Locality JW66-12, Sample 43, 97-99 feet above the base of the Bearpaw Formation.

Distribution: This species is rare. A total of 61 specimens were found at the above locality in Samples 35-49, from the interval 70-115 feet above the base of the Bearpaw formation.

Wickenden (1948, p. 81) described this species from the

upper part of the Lea Park Formation in southwestern Saskatchewan. Wall (1967, p. 98) found similar forms in the Nomad Member of the Wapiabi Formation on Thistle Creek in the central Alberta Foothills. Tappan (1962, p. 195) reported the same species from the Schrader Bluff Formation in Alaska.

Remarks: Some of the specimens are poorly preserved or partially pyritized. The stellate supplementary chambers are often not readily visible in the poorly preserved forms.

Genus VALVULINERIA Cushman, 1926

VALVULINERIA sp. cf. V. UMBILICATA (d'Orbigny)

Plate 3, figures 2-4.

Valvulineria cf. umbilicate (d'Orbigny). Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 139, pl. 57, figs. 9-12 --- Frizzell, 1954, Texas, Bur. Econ. Geol. Rept. Invest. 22, p. 123, pl. 18, figs. 38, 39 --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 99, pl. 6, figs. 28-33; pl. 9, figs. 22-24.

Description: Test rotaloid, planoconvex with spiral side flat and umbilical side convex, periphery broadly rounded, peripheral outline slightly lobulate; chambers arranged in two whorls, chambers in outer whorl six, much larger than earlier chambers, the final chamber with a large flap or extension covering the umbilicus and the ends of the previous

chambers; sutures distinct, slightly curved, slightly depressed; wall calcareous, finely perforate, smooth; aperture a low slit at the base of the last chamber extending from near the periphery into the umbilicus; colorless.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen (fig. 2)	0.26	0.21	0.12
Figured specimen (fig. 3)	0.45	0.38	0.25
Figured specimen (fig. 4)	0.48	0.40	0.31

Types: The figured specimens (figs. 2-3) are from Locality JW66-12, Sample 29, 56-58 feet above the base of the formation and figured specimen (fig. 4) from the same Locality in Sample 33, 65-67 feet above the base of the Bearpaw.

Distribution: This species is rare and was observed only in the above Locality. Apart from six specimens which were found in the above sample,31 others were found in Samples 33 to 41 from the interval 65-94 feet above the base os the Bearpaw Formation.

Wall (1967, p. 99) reported this species from the Wapiabi Formation in the Rocky Mountain Foothills in Alberta. The species also occurs in the Navarro and Taylor Groups of the Gulf Coastal Region of the United States.

Remarks: There are some variations in the umbilical flaps of the Bearpaw specimens. The umbilical flaps of most of the specimens are wide and broad and cover nearly all the umbilicus and the ends of the previous chambers. The umbilical flaps of a few other specimens are narrow and partially cover the umbilicus.

Superfamily SPIRILLINACEA Reuss, 1862

Family SPIRILLINIDAE Reuss, 1862

Genus SPIRILLINA Ehrenberg, 1843

SPIRILLINA ? sp.

Plate 3, figure 5.

Description: Test discoidal, planispiral, of about six to eight coils around a small proloculum, coiling regular with slight increase in diameter of tube in outer whorls; spiral suture distinct, depressed; wall calcareous, somewhat granular, aperture not observed, presumably formed by open end of the tube; colorless.

Dimensions:

	Diameter (mm.)	Thickness (mm.)
Figured specimen	0.25	0.02

Types: The figured specimen is from Locality JW66-12, Sample 31, 60-62 feet above the base of the Bearpaw Formation.

Distribution: A total of 13 specimens were found at the above locality in Samples 29, 31, 33 from the interval 56-67 feet above the base of the Bearpaw Formation.

Remarks: The specimens react with dilute Hydrochloric acid and under the petrographic microscope show high relief characteristic of calcite. However, the walls are somewhat granular and it is not certain whether they are composed of an aggregate of fine calcite grains or a single calcite crystal which is characteristic of the genus.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family HETEROHELICIDAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

HETEROHELIX GLOBULOSA (Ehrenberg)

Plate 3, figure 6.

Gumbelina globulosa (Ehrenberg). Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 105-106, pl. 45, figs. 9-15 (synonymy) --- Stelck and Wall, 1954, Res. Coun. Alberta Rept. 68, p. 22, pl. 2, figs. 20a-b --- Frizzell, 1954, Texas Bur. Econ. Geol. Rept. Invest. 22, p. 109, pl. 15, figs. 24-27.

Heterohelix globulosa (Ehrenberg). Montanaro Gallitelli, 1957, U.S. Nat. Mus. Bull. 215, p. 137, pl. 31, figs. 12-15 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper

236-C, p. 196, pl. 55, figs. 1, 2 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 21, pl. 3, figs. 11a-b --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 102, pl. 3, figs. 26-37.

Description: Test small, gently flaring from bluntly pointed initial end, periphery outline indented; chambers biserial, enlarging rapidly in size and becoming progressively more inflated as added with later ones nearly globular, five to six pairs present; sutures distinct, depressed, oblique; wall calcareous, hyaline, finely perforate, smooth; aperture a broadly arched opening at the inner margin of the last chamber; colorless.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype	0.24	0.16

Types: The hypotype is from Locality JW66-12, Sample 35, 70-72 feet above the base of the Bearpaw Formation.

Distribution: Seventeen specimens of this species were found at the above Locality in Samples 41 and 43 from the interval 92-99 feet above the base of the Bearpaw Formation.

This species is widespread. Stelck and Wall (1954, p. 22) reported it from the Kaskapau Formation in the plains

region of northwestern Alberta. Wall (1960, p. 29; 1967, p. 104) noted it from the Puskwaskau Shale and the Vimy Member of the Blackstone Formation, respectively. North and Caldwell (1964, p. 21) recorded it in the Lea Park Formation in south-central Saskatchewan.

The species also occurs in the Navarro and Taylor Groups of the Gulf Coastal Region of the United States, according to Cushman (1946, p. 106) and in the Seabee Formation of Alaska, according to Tappan (1962, p. 196).

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA ASPERA (Ehrenberg)

Plate 3, figure 7.

Globigerinella aspera (Ehrenberg). Carman, 1929, Jour. Paleont., vol. 3, no. 3, p. 315, pl. 34, fig. 6 --- Jennings, 1936, Bull. Am. Paleont., vol. 23; no. 78, p. 194, pl. 4, p. 337, pl. 48, fig. 9.

Globigerina aspera (Ehrenberg). Wall, 1960, Res. Coun. Alberta Bull. 6, p. 32, pl. 5, figs. 13, 14 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 25, pl. 4, figs. 8a-b.

"Globigerinella" aspera (Ehrenberg). Graham and Church, 1963, Stanford Univ. Publ., Geol. Sc., vol. 8, no. 1,

p. 64, pl. 7, fig. 17.

Description: Test small, planispiral, evolute, periphery rounded, lobulate; six chambers in ultimate whorl, enlarging fairly rapidly, the last three much larger and more inflated than previous chambers; sutures distinct, depressed, radial; wall calcareous, finely perforate, smooth to faintly hispid; aperture equatorial, a moderately arched opening at the base of the terminal chamber.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Hypotype	0.18	0.15	0.05

Types: The hypotype is from Locality JW66-12, Sample 43, 97-99 feet above the base of the Bearpaw Formation.

Distribution: Only the hypotype was found. It was associated with 11 specimens of Heterohelix globulosa (Ehrenberg) in the above sample.

Nauss (1947, p. 336) recorded this species from the lower Lea Park Shale of east-central Alberta. Wall, (1960, p. 32) illustrated it from the first (upper) white-speckled shale "zone" of the Puskwaskau Formation on the Bad Heart River, North and Caldwell (1964, p. 25) reported it from

the Lea Park Formation in south-central Saskatchewan.

The species also occurs in the Cretaceous rocks of California, United States.

Family ROTALIPORIDAE Sigal, 1958

Genus HEDBERGELLA Bronnimann and Brown, 1958

HEDBERGELLA sp. cf. H. DELRIOENSIS (Carsey)

Plate 3, figure 8.

? Globigerina cretacea d'Orbigny var. del rioensis (sic!) Carsey, 1926, Univ. Texas Bull. 2612, p. 43.

? Globigerina cretacea d'Orbigny. Tappan, 1940, Jour. Paleont., vol. 14, no. 2, p. 121, pl. 19, figs. 11a-c --- Stelck and Wall, 1954, Res. Coun. Alberta Rept. 68, p. 21-22, pl. 2, figs. 21, 22 (not Globigerina cretacea d'Orbigny, 1840).

? Globigerina delrioensis Carsey. Frizzell, 1954, Texas, Bur. Econ. Geol. Rept. Invest. 22, p. 127, pl. 20, figs. 1a-c.

? Hedbergella delrioensis (Carsey). Loeblich and Tappan, 1961, Micropaleont., vol. 7, no. 3, p. 275, pl. 2, figs. 11-13 --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 105, pl. 3, figs. 1-12; pl. 13, figs. 13-21.

Description: Test medium size, rotaloid, peripheral margin lobulate, spiral side with low spire, umibilical

side moderately deep; chambers arranged in two whorls, inflated, subglobular, increasing rapidly in size as added, five chambers in outer whorl; sutures distinct, deeply depressed, straight, radial; wall calcareous, pyritized, surface somewhat granular; aperture obscure.

Dimension:

	Diameter (mm.)	Thickness (mm.)
Figured specimen	0.30	0.12

Types: The figured specimen is from Locality JW66-12, Sample 45, 102-104 feet above the base of the Bearpaw Formation.

Distribution: Only the figured specimen was found in the formation.

This species has been reported from the lower (second) white-speckled shale "zone" within the central part of the Kaskapau Formation, Stelck and Wall, (1954, p. 106); from the Vimy Member of the Blackstone Formation and the Hanson Member of the Wapiabi Formation, Wall (1967, p. 106).

Remarks: The only specimen obtained is highly pyritized and partially deformed.

Superfamily CASSIDULINACEA d'Orbigny, 1839

Family NONIONIDAE Schultze, 1854

Genus NONIONELLA Cushman, 1926

NONIONELLA sp. cf. N. CRETACEA Cushman

Plate 3, figure 9.

? Nonionella cretacea Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 101, pl. 43, fig. 24.

Description: Test small, compressed, periphery narrowly rounded; test trochospiral, with low spire and asymmetrical final chamber overhanging umbilicus; chambers about eight, increasing rapidly in size as added, inflated; sutures distinct, depressed, radial to slightly curved; wall calcareous, smooth, usually pyritized; aperture a narrow opening at the periphery and extending over onto the umbilical side, at the base of the final chamber.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen	0.22	0.16

Types: The figured specimen is from Locality JW66-12, Sample 37, 75-77 feet above the base of the Bearpaw Formation.

Distribution: This species is rare. Two specimens were found in the above sample and one specimen from Sample

29, at the same Locality from the interval 56-58 feet above the base of the formation.

The species occurs in the Navarro and Taylor Groups of the Gulf Coastal Region of the United States and in Upper Cretaceous rocks of Mexico (Cushman, 1946, p. 101).

Remarks: The Bearpaw specimens have fewer chambers compared with the Gulf Coast specimens.

Family ALABAMINIDAE Hofker, 1951

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA sp. cf. G. DEPRESSA (Alth)

Plate 3, figure 10, 11.

? Gyroidina depressa (Alth). Cushman, 1946, U.S. Geol. Prof. Paper 206, p. 139, pl. 58, figs. 3-4, (not 1-2).

Description: Test trochospiral, biconvex with spiral side nearly flat, periphery rounded, umbilicus open; chambers about eight in the last whorl, increasing gradually in size; sutures distinct, flush with the surface in the earlier portion of the test and becoming progressively depressed in the later portion of the test, curved; wall calcareous, finely perforate, smooth; aperture a low slit at the base of the last chamber extending from the periphery into the umbilicus;

color grey to light yellow.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen (fig. 10)	0.23	0.21	0.12
Figured specimen (fig. 11)	0.25	0.22	0.12

Types: The figured specimens are from Locality JW66-12, Sample 35, 70-72 feet above the base of the Bearpaw.

Distribution: Most occurrences of this species were recorded at Locality JW66-12. Thirty-seven specimens were found in Sample 29, 56-58 feet above the base of the Bearpaw and a total of 86 in Samples 33 to 49 from the interval 66-115 feet above the base of the formation. The species also occurs at Localities JW66-13 and JW66-14 but are rare.

The species occurs in the Navarro, Taylor and Austin Groups of the Gulf Coastal Region of the United States.

Remarks: The general characters of the Bearpaw specimens seem to be closely matched with those of Gulf Coast specimens except that the Bearpaw specimens have about eight chambers as compared with 10 to 12 chambers in the Gulf Coast specimens.

Family ANOMALINIDAE Cushman, 1927

Genus ANOMALINOIDES Brotzen, 1942

ANOMALINOIDES sp.

Plate 3, figure 12.

Description: Test medium size, compressed, nearly planispiral, asymmetrical, periphery rounded, peripheral margin entire to slightly indented; chambers arranged in two whorls, all chambers visible on spiral side, evolute with an umbonal boss, chambers of the final whorl visible on the opposite side and with a small portion of the inner whorl visible in the shallow umbilicus, nearly involute; chambers numerous, usually distinct, 12 in number in the last whorl, increasing gradually in size as added with the later chambers becoming gradually inflated; sutures distinct, flush with the surface in the initial portion of the final whorl, depressed in the later portion of the final whorl; wall calcareous, perforate, smooth; aperture a slit on the periphery extending onto the spiral side with a slight lip; color greyish.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.20	0.18	0.07

Types: The figured specimen is from Locality JW66-13, Sample 1, 200-210 feet above the base of the Bearpaw Formation.

Distribution: This species occurs most characteristically in the above locality. One hundred and eighty-seven specimens were found in Sample 1 and 75 specimens in Sample 2.

Remarks: Although this specimen seems to be similar with A. henbesti (Plummer), the test is much smaller, the chamber arrangement different and the wall less coarsely perforate.

Family GAVELINELLIDAE Hofker, 1956

Genus GAVELINELLA Brotzen, 1942

GAVELINELLA sp. cf. G. AWUNENSIS Tappan

Plate 3, figure 13.

? Gavelinella awunensis Tappan, 1960, Am. Assoc. Petroleum Geologists Bull., vol. 44, no. 3, p. 296, pl. 2, figs. 15-16 --- 1962, U.S. Geol. Prof. Paper 236-C, p. 197, pl. 56, figs. 1-7.

Description: Test planispiral, nearly biconvex, periphery rounded, umbilical side umbonate; chambers about twelve in the final whorl, increasing gradually in size; sutures distinct, gently curved, flush with the surface; wall calcareous, hyaline, perforate, smooth; aperture a low interomarginal slit extending from the peripheral margin onto the umbilical side, beneath the umbilical chamber flaps.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.25	0.20	0.11

Types: The figured specimen is from Locality JW66-12, Sample 37, 70-72 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare. Only two specimens were found in the above sample.

Tappan (1962, p. 197) recorded the species from the Torok and Topagoruk Formations in Alaska.

Remarks: The Bearpaw specimens are similar to the Torok and Topagoruk specimens in the number of chambers, chamber arrangement, suture and aperture shapes. However, the Bearpaw specimens are somewhat biconvex and less plano-convex than the Torok and Topagoruk specimens.

GAVELINELLA ? sp.

Plate 3, figure 14.

Description: Test medium size, compressed, rotaloid with spiral side slightly convex and umbilical side fairly flat, periphery subrounded, peripheral margin entire to

slightly lobulate, earlier whorl partly exposed on both sides at the centre; chambers from nine to ten in the last whorl, slightly inflated, gradually and uniformly increasing in size as added; sutures flush with the surface in the initial portion of the last whorl, slightly depressed in the later whorl, curved; wall calcareous, hyaline, perforate, smooth; aperture a peripheral slit extending onto the umbilical side, with a slight lip; color pinkish yellow.

Dimensions:

	Maximum Diameter (mm.)	Minimum Diameter (mm.)	Thickness (mm.)
Figured specimen	0.30	0.25	0.11

Types: The figured specimen is from Locality JW66-12, Sample 39, 81-83 feet above the base of the Bearpaw Formation.

Distribution: This species is common in a few samples at the above locality. Eighty-eight specimens were found in Sample 29, 56-58 feet above the base of the Bearpaw and a total of 1041 specimens were found in Samples 33 to 49, from the interval 65-115 feet above the base of the formation. The species seems to be absent in the other localities.

Remarks: The coiling pattern of this species varies from fairly symmetrical to asymmetrical with the test being somewhat biconvex to slightly concave. It is difficult to

determine which side of the test is the spiral side. The specimens were assigned to the genus Gavelinella on the assumption that the umbilical side of the test varied from relatively biconvex to slightly concave and the aperture extended from the periphery into the umbilicus.

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APPENDIX - COLLECTION AND PREPARATION OF SAMPLES FOR MICROPALEONTOLOGICAL STUDIES

Sampling Procedure

Two techniques of collecting samples were used; channel sampling technique and "spot" sampling technique. The technique used in collecting samples from an outcrop depends on the lithology and the general condition of the outcrop. Channel sampling technique was used in outcrops where the shales seemed free from a noticeable amount of sands or silts, and the shales appeared potentially microfossiliferous. A channel of 2 feet 8 inches was dug out in the outcrop surface until fresh shales were encountered. About 500 grams of the fresh shale chips from the dug-out surface were collected, described and put into a labelled bag. The process was repeated on the next 2 feet 8 inches section. In this manner, samples were collected continuously along the entire outcrop section.

The "spot" sampling technique was used in outcrops where the shales appeared silty, deeply weathered or covered by a thick talus creep. A trench measuring about three to four feet in diameter was dug out in a selected or "spot" area in the outcrop until fresh shales were met. Samples were collected from the fresh shale chips. Intervals of "spot" sampling technique were variable. If the outcrop section consisted of interbeddings of shales and silty shales, samples were generally collected from the shaley beds.

In both channel and "spot" sampling techniques, sampling was from the base of the outcrop towards the top in order to eliminate any possible contamination of the samples.

Collecting Localities

The collecting localities are shown in Figure 6 and a composite section (simplified) of the Bearpaw Formation showing the sampled sections is shown in Figure 7.

Locality JW66-12. St. Mary River Valley
SE¼ Sec. 2, Tp. 7, R22W4

About 170 feet of the basal portion of the Bearpaw Formation outcrops in this locality (Figure 8). The formation overlies directly about two feet of brown ferruginous concretion which forms the contact between the Bearpaw Formation and the underlying Lethbridge Coal Measures of the Oldman Formation. Ash bed 'A' and a few other thin ash beds and thin concretionary bands are conspicuous in the weathered surface. The Bearpaw shales are weathered to rusty brown or chocolate brown.

Eight samples, JW66-12-1 to JW66-12-8, were collected from the shale interbeddings forming the upper 22 feet of the Lethbridge Coal Measures (Oldman Formation). Fifty-nine samples, JW66-12-9 to JW66-12-67 were collected from the Bearpaw shales at this locality by channel sampling techni-

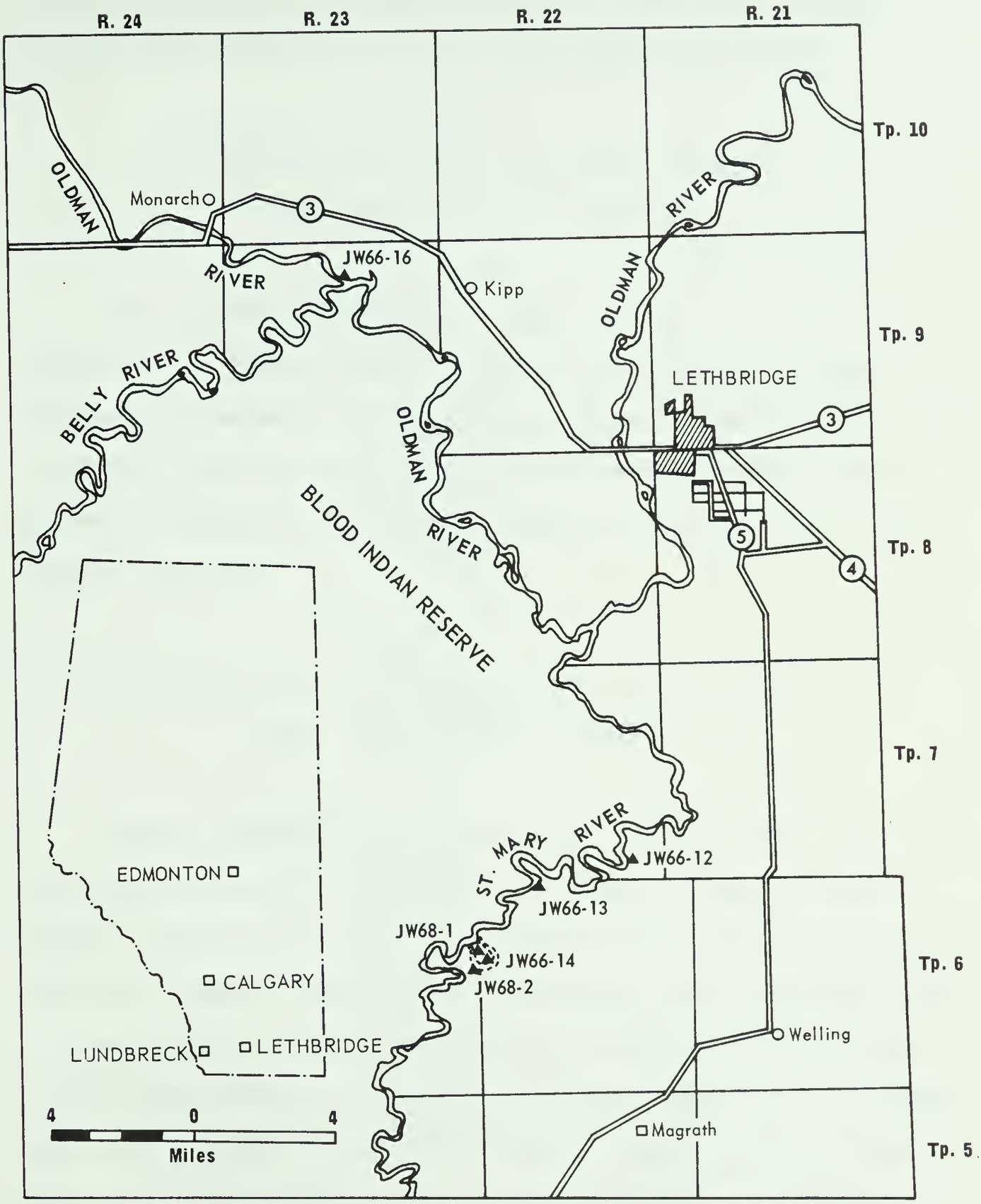


FIGURE 6: INDEX MAP OF LETHBRIDGE AREA, ALBERTA, SHOWING COLLECTING LOCALITIES

▲ COLLECTING LOCALITY(prefixed JW)

⑤ HIGHWAY NUMBER

que at intervals of 2 feet 8 inches. The fresh Bearpaw shales are dark grey to bluish grey and well bedded.

Locality JW66-13. St. Mary River Valley

NE¼, Sec. 32, Tp. 6, R22W4

The Magrath Sandstone outcrops in this locality (Figure 9). Sample JW66-13-1 was collected from 10 feet of shales just beneath the Magrath Sandstone. Samples JW66-13-2 to JW66-13-16 were collected from 93 feet of shaley beds above the Magrath Sandstone by channel sampling at 5 feet 4 inches intervals.

Locality JW66-14. St. Mary River, Ox-bow Lake

NW¼, Sec. 19, Tp. 6, R22W4

The Kipp Sandstone outcrops here (Figure 10). It is silty and shaley at the base, with about 15 feet of cliff forming sands at the top. Seventy-two feet of section was sampled. Samples JW66-14-1 to JW66-14-7 were collected from 27 feet of silty shales underlying the cliff forming sands of the Kipp Sandstone by "spot" sampling technique. Samples JW66-14-8 to JW66-14-15 were obtained from 45 feet of shales above the Kipp Sandstone by channel sampling at 5 feet 4 inches intervals.

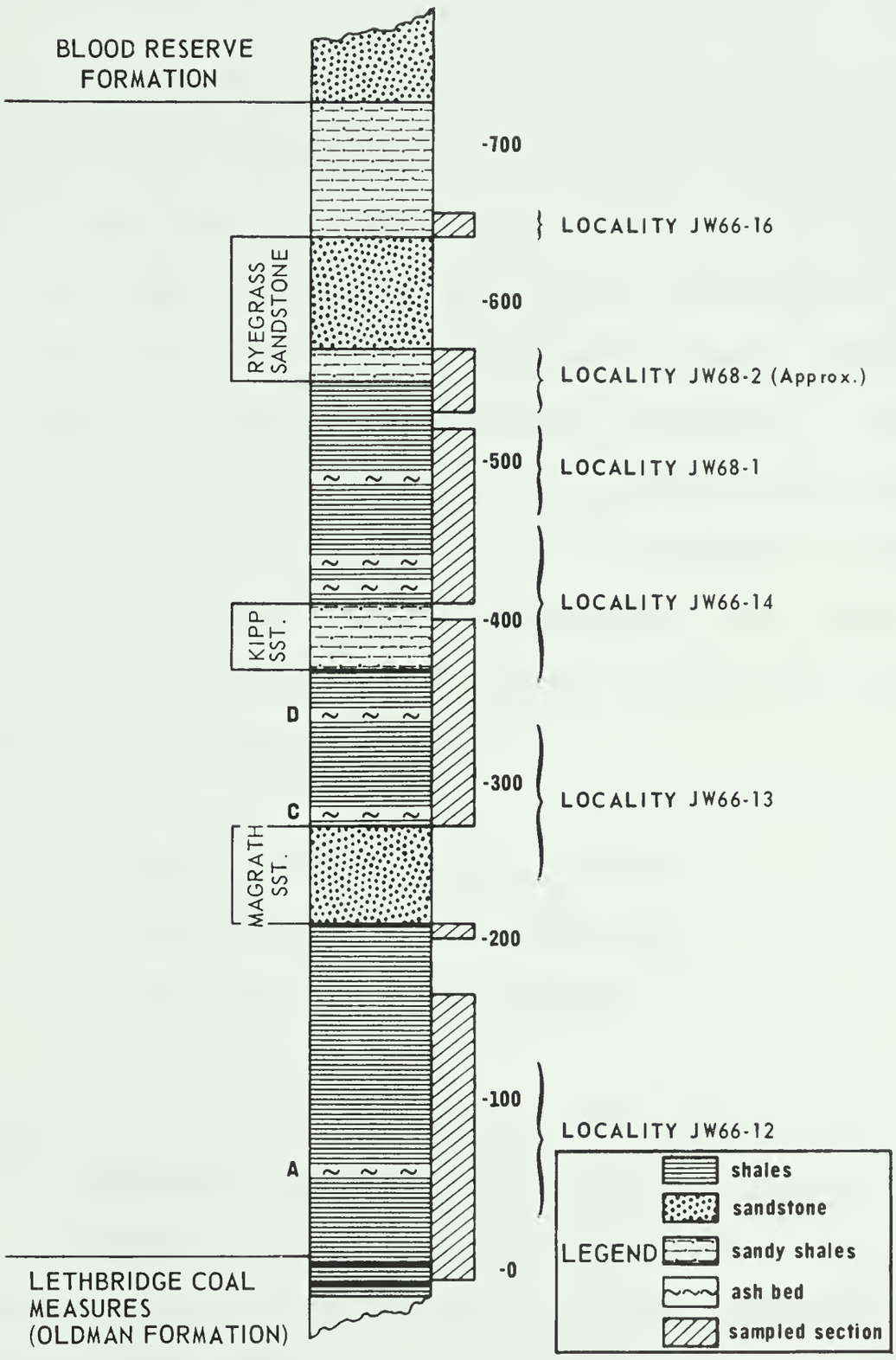


FIGURE 7: COMPOSITE SECTION (SIMPLIFIED) OF THE BEARPAW FORMATION, LETHBRIDGE AREA, ALBERTA, SHOWING SAMPLED SECTIONS.

Locality JW68-1. St. Mary River, Ox-bow Lake

SE¼, Sec. 25, Tp. 6, R23W4

About 50 feet of shales occurring just about half-way between the Kipp Sandstone and the Ryegrass Sandstone outcrops in this locality (Figure 11). The outcrop forms a steep-sided slope with the slope surface covered by a thick talus creep. Samples JW68-1-1 to JW68-1-8 were collected by "spot" sampling technique at variable intervals of four feet and five feet. A three inch ash bed occurs about half-way up the outcrop section. This ash bed is thought to be equivalent to the six inch ash bed recorded by Link and Childerhose (1931) which occurs about midway between the Kipp Sandstone and the Ryegrass Sandstone.

Locality JW68-2, St. Mary River,

Southwest Bend of Ox-bow Lake

NE¼, Sec. 24, Tp. 6, R23W4

About 40 feet of transitional beds occurring just beneath the Ryegrass Sandstone is exposed as a cliff in this area. The shales are very silty and highly weathered. Three samples JW68-2-1 to JW68-2-3 were collected by "spot" sampling technique at variable intervals.

Locality JW66-16. Oldman River Valley,
Just above Junction with Belly River
SW¼, Sec. 34, Tp. 9, R23W4

The Ryegrass Sandstone outcrops here (Figure 12). Two samples were collected. Sample JW66-16-1 was collected from six feet thick sandy shales which overlie directly the Ryegrass Sandstone. One foot thick sands overlie the sandy shales, followed by a five feet thick silty shales from which sample JW66-16-2 was collected. Thick deposit of river gravels overlies the silty shales.

Sample Preparation

The standard laboratory procedure for preparation of samples for microfaunal studies was used:

i. The samples were first examined and described.

ii. About 150 gms. of the sample was weighted and disaggregated in a beaker of water. Period of time which was needed for the break down of the samples depended on the degree of induration. In some cases detergent was added to accelerate the process.

iii. After disaggregation, the samples were washed in the "miner's pan" and then through the 200 mesh screen to get rid of the colloidal matter and the clay particles.

iv. The residue was dry-sieved through the 20, 40, 60, 80, 120 mesh screens.

FIGURE 8: Locality JW66-12. St. Mary River valley; SE¼, Sec. 2, Tp. 7, R22W4:

Exposure of the basal portion of the Bearpaw Formation and the underlying Lethbridge Coal Measures of the Oldman Formation. The contact between the Bearpaw and the Oldman is formed by a distinct, brown, ferruginous sandstone about two feet thick (C). Ash bed "A" (Link and Childerhose, 1931), few other thin ash beds and brown concretionary bands are conspicuous in the weathered surface. The beds are displaced by a small fault (F).

FIGURE 9: Locality JW66-13. St. Mary River valley; NE¼, Sec. 32, Tp. 6, R22W4.

Exposure of the Magrath Sandstone (M) overlain by thick deposit of shales, ash beds "C" and "D" of Link and Childerhose (1931) are conspicuous in the surface.

FIGURE 10: Locality JW66-14. St. Mary River, Ox-bow Lake; NW¼, Sec. 19, Tp. 6, R22W4.

Exposure of the Kipp Sandstone. The basal portion (L) is shaley and the upper 15 feet forms a sandy cliff (M). Thick deposit of shales overlies the sandy cliff.

FIGURE 11: Locality JW68-1. St. Mary River, Ox-bow Lake; SE¼, Sec. 25, Tp. 6, R23W4.

Exposure of about 50 feet of shales (occuring just about half-way between the Kipp Sandstone and the Ryegrass Sandstone, Fig. 7). Thick talus creep covers the outcrop. Samples were collected by "spot" sampling technique. The sampling spots are shown by the holes (H) on the surface.

FIGURE 12: Locality JW66-16. Oldman River valley, just above junction with Belly River; SW¼, Sec. 34, Tp. 9, R23W4.

Exposure of the Ryegrass Sandstone (V). Six feet thick greenish sandy shales (W) overlie the Ryegrass. This is followed by about a foot thick sand (X), five feet thick silty shales (Y) and a thick deposit of river gravels (Z).

EXPLANATION OF PLATE 1

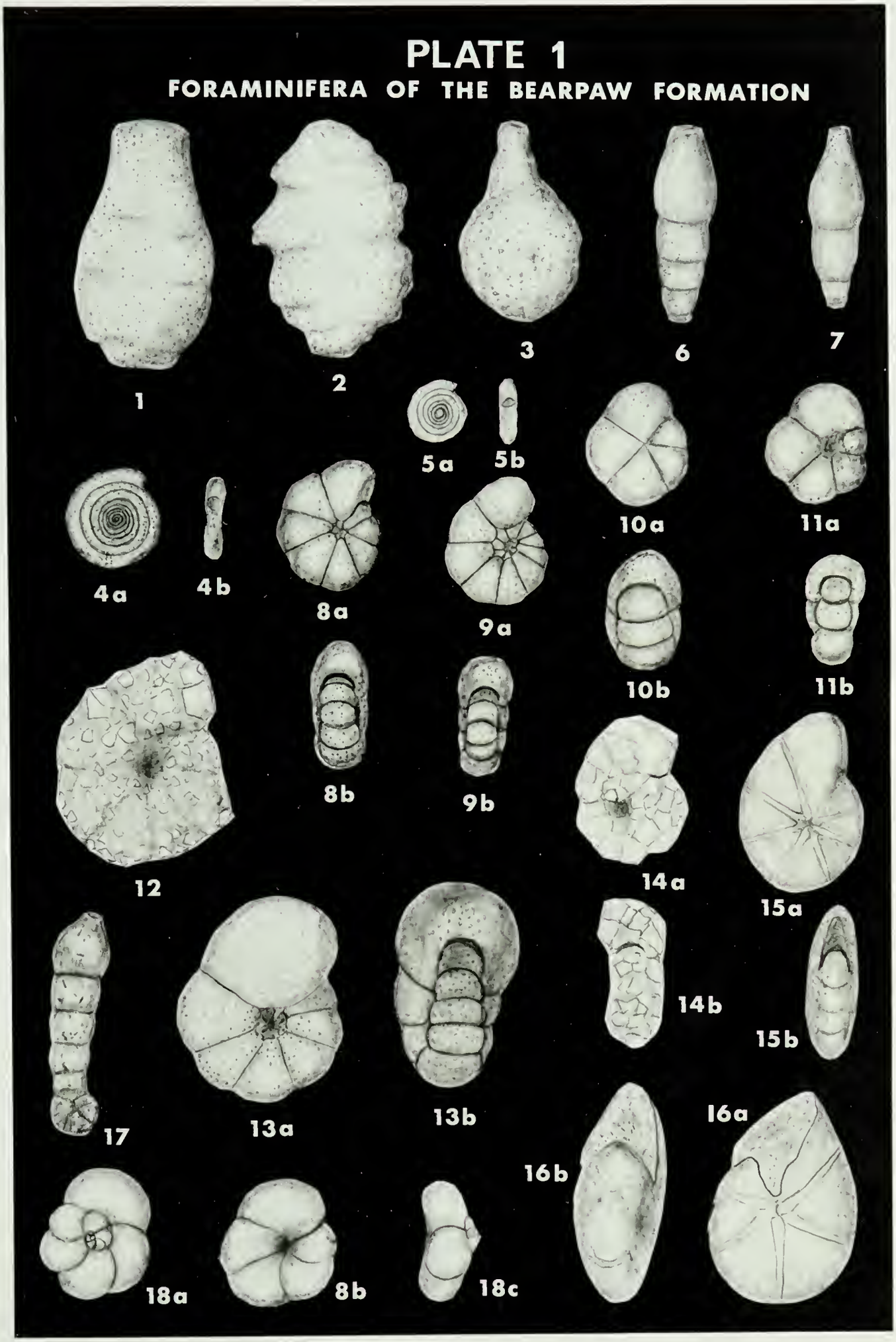
Magnification X 50 unless otherwise stated

Footage measured above the base of Bearpaw Formation

EXPLANATION OF PLATE 1 cont'd.

PLATE 1

FORAMINIFERA OF THE BEARPAW FORMATION



EXPLANATION OF PLATE 2

Magnification X 50 unless otherwise stated

Footage measured above the base of Bearpaw Formation

EXPLANATION OF PLATE 2 cont'd.

EXPLANATION OF PLATE 2 cont'd.

Figure | Page

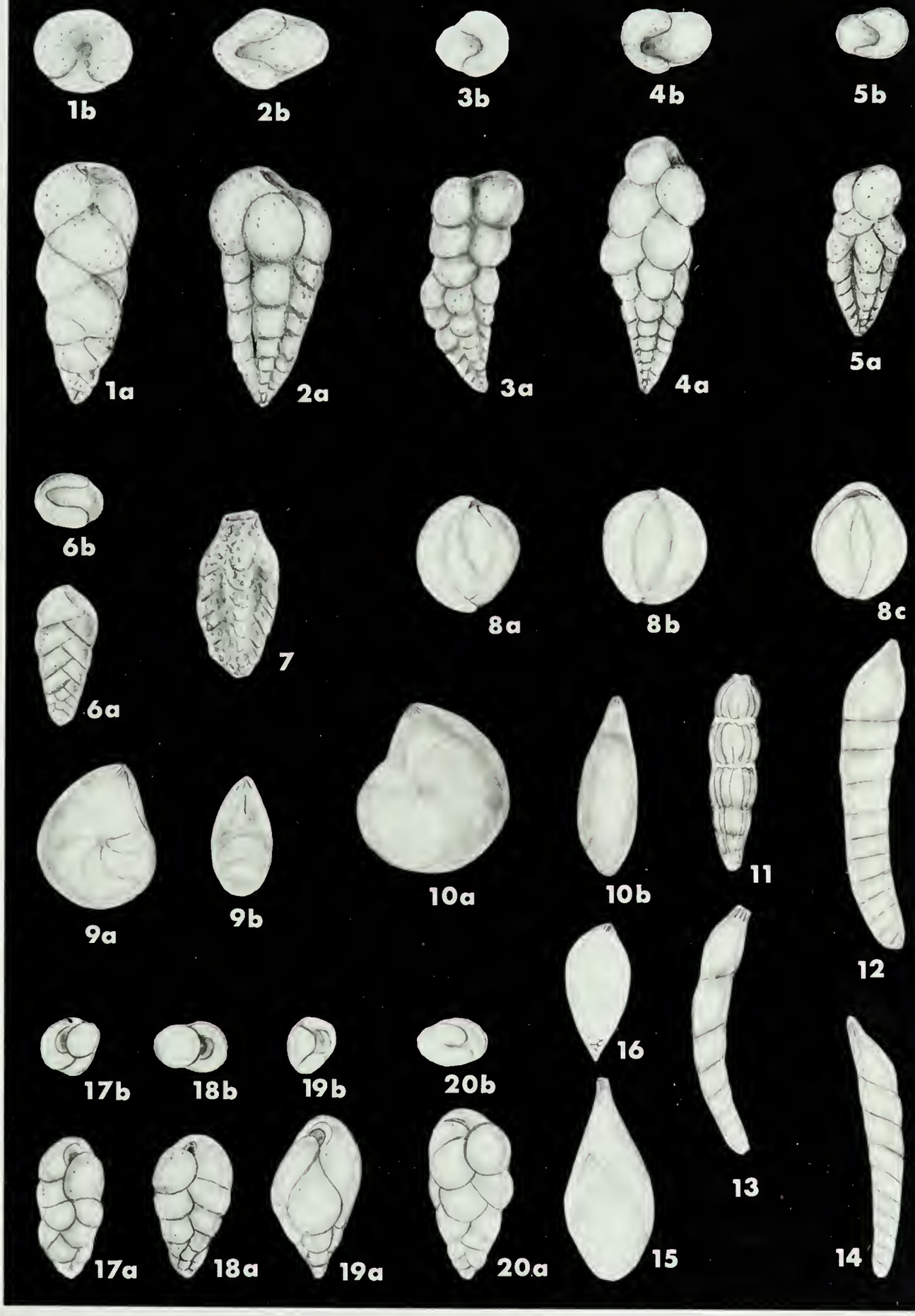
17, 18. Neobulimina canadensis Cushman and Wickenden
Locality JW66-12, Sample 37, 75-77 feet; Magnification: Hypotype 17 X 68; Hypotype 18 X 76; 17a, 18a - side views; 17b, 18b - apertural views..... 77

19. Praebulimina venusae (Nauss)
Locality JW66-12, Sample 37, 75-77 feet; Magnification X 80; 19a - side view; 19b - apertural view..... 80

20. Praebulimina sp. cf. P. kickapooensis (Cole)
Locality JW66-12, Sample 41, 92-94 feet; Magnification X 78. 20a - side view; 20b - apertural view..... 81

PLATE 2

FORAMINIFERA OF THE BEARPAW FORMATION



EXPLANATION OF PLATE 3

Magnification X 50 unless otherwise stated

Footage measured above the base of Bearpaw Formation

EXPLANATION OF PLATE 3 cont'd.

Figure | Page

8. Hedbergella sp. cf. H. delrioensis (Carsey)
Locality JW66-12, Sample 45, 102-104 feet; Magnification X 63; 8a - side view; 8b - apertural view..... 92

9. Nonionella sp. cf. N. cretacea Cushman
Locality JW66-12, Sample 37, 75-77 feet; Magnification X 81; 9a - spiral view; 9b - umbilical view; 9c - apertural view... 94

10, 11. Gyroidina sp. cf. G. depressa (Alth)
Locality JW66-12, Sample 35, 70-72 feet; 10a, 11a - spiral views; 10b, 11b - umbilical views; 10c, 11c - peripheral views..... 95

12. Anomalinoides sp.
Locality JW66-13, Sample 1, 200-210 feet; Magnification X 110; 12a - spiral view; 12b - umbilical view; 12c - peripheral view..... 97

13. Gavelinella sp. cf. G. awunensis Tappan
Locality JW66-12, Sample 37, 70-72 feet; Magnification X 92; 13a - spiral view; 13b - umbilical view; 13c - peripheral view..... 98

EXPLANATION OF PLATE 3 cont'd.

Figure | Page

14. *Gavelinella*? *sp*.
Locality JW66-12, Sample 39, 81-83 feet; Magnification X 74; 14a - spiral ? view: 14b - umbilical ? view; 14c - peripheral view..... 99

PLATE 3

FORAMINIFERA OF THE BEARPAW FORMATION